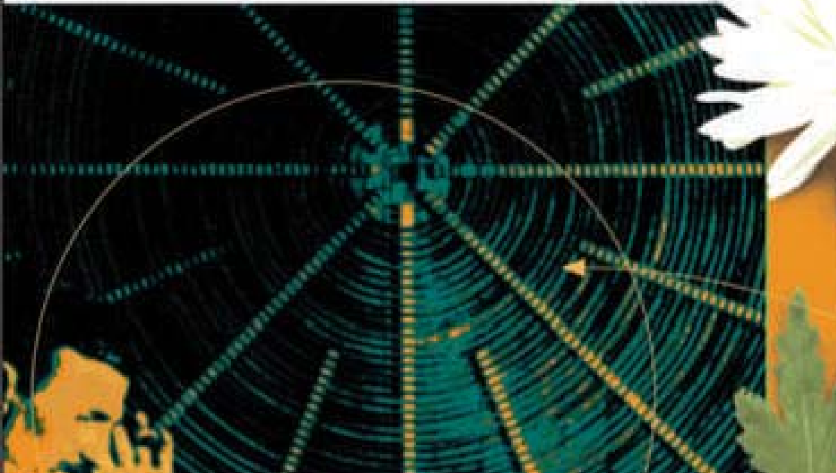

U·X·L Encyclopedia of Science

Second Edition

Volume 1: A-As

Rob Nagel, editor

U·X·L Encyclopedia of Science

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10 9 8 7 6 5 4 3 2 1

Table of Contents

Reader's Guide vii

Entries by Scientific Field ix

Volume 1: A-As 1
Where to Learn More xxxi
Index xxxv

Volume 2: At-Car 211
Where to Learn More xxxi
Index xxxv

Volume 3: Cat-Cy 413
Where to Learn More xxxi
Index xxxv

Volume 4: D-Em 611
Where to Learn More xxxi
Index xxxv

Volume 5: En-G 793
Where to Learn More xxxi
Index xxxv

Volume 6: H-Mar 1027
Where to Learn More xxxi
Index xxxv

Volume 7: Mas-O 1235
Where to Learn More xxxi
Index xxxv

Contents

Volume 8: P-Ra 1457
Where to Learn More xxxi
Index xxxv

Volume 9: Re-St 1647
Where to Learn More xxxi
Index xxxv

Volume 10: Su-Z 1829
Where to Learn More xxxi
Index xxxv

Reader's Guide

Demystify scientific theories, controversies, discoveries, and phenomena with the *U•X•L Encyclopedia of Science,* Second Edition.

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In addition to solid information, the *Encyclopedia* also provides these features:

- "Words to Know" boxes that define commonly used terms
- Extensive cross references that lead directly to related entries
- A table of contents by scientific field that organizes the entries
- More than 600 color and black-and-white photos and technical drawings
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Entries by Scientific Field

Boldface indicates volume numbers.

Acoustics

Acoustics **1**:17
Compact disc **3**:531
Diffraction **4**:648
Echolocation **4**:720
Magnetic recording/ audiocassette **6**:1209
Sonar **9**:1770
Ultrasonics **10**:1941
Video recording **10**:1968

Aerodynamics

Aerodynamics **1**:39
Fluid dynamics **5**:882

Aeronautical engineering

Aircraft **1**:74
Atmosphere observation **2**:215
Balloon **1**:261
Jet engine **6**:1143
Rockets and missiles **9**:1693

Aerospace engineering

International Ultraviolet Explorer **6**:1120
Rockets and missiles **9**:1693
Satellite **9**:1707
Spacecraft, manned **9**:1777
Space probe **9**:1783
Space station, international **9**:1788
Telescope **10**:1869

Agriculture

Agriculture **1**:62
Agrochemical **1**:65
Aquaculture **1**:166
Biotechnology **2**:309
Cotton **3**:577
Crops **3**:582
DDT (dichlorodiphenyl-trichloroethane) **4**:619
Drift net **4**:680
Forestry **5**:901
Genetic engineering **5**:973
Organic farming **7**:1431
Slash-and-burn agriculture **9**:1743
Soil **9**:1758

Anatomy and physiology

Anatomy **1**:138
Blood **2**:326

Brain **2:**337
Cholesterol **3:**469
Chromosome **3:**472
Circulatory system **3:**480
Digestive system **4:**653
Ear **4:**693
Endocrine system **5:**796
Excretory system **5:**839
Eye **5:**848
Heart **6:**1037
Human Genome Project **6:**1060
Immune system **6:**1082
Integumentary system **6:**1109
Lymphatic system **6:**1198
Muscular system **7:**1309
Nervous system **7:**1333
Physiology **8:**1516
Reproductive system **9:**1667
Respiratory system **9:**1677
Skeletal system **9:**1739
Smell **9:**1750
Speech **9:**1796
Taste **10:**1861
Touch **10:**1903

Anesthesiology

Alternative medicine **1:**118
Anesthesia **1:**142

Animal husbandry

Agrochemical **1:**65
Biotechnology **2:**309
Crops **3:**582
Genetic engineering **5:**973
Organic farming **7:**1431

Anthropology

Archaeoastronomy **1:**171
Dating techniques **4:**616
Forensic science **5:**898
Gerontology **5:**999
Human evolution **6:**1054
Mounds, earthen **7:**1298
Petroglyphs and pictographs **8:**1491

Aquaculture

Aquaculture **1:**166
Crops **3:**582
Drift net **4:**680
Fish **5:**875

Archaeology

Archaeoastronomy **1:**171
Archaeology **1:**173
Dating techniques **4:**616
Fossil and fossilization **5:**917
Half-life **6:**1027
Nautical archaeology **7:**1323
Petroglyphs and pictographs **8:**1491

Artificial intelligence

Artificial intelligence **1:**188
Automation **2:**242

Astronomy

Archaeoastronomy **1:**171
Asteroid **1:**200
Astrophysics **1:**207
Big bang theory **2:**273
Binary star **2:**276
Black hole **2:**322
Brown dwarf **2:**358
Calendar **2:**372
Celestial mechanics **3:**423
Comet **3:**527
Constellation **3:**558
Cosmic ray **3:**571

Cosmology **3:**574
Dark matter **4:**613
Earth (planet) **4:**698
Eclipse **4:**723
Extrasolar planet **5:**847
Galaxy **5:**941
Gamma ray **5:**949
Gamma-ray burst **5:**952
Gravity and gravitation **5:**1012
Infrared astronomy **6:**1100
International Ultraviolet Explorer **6:**1120
Interstellar matter **6:**1130
Jupiter (planet) **6:**1146
Light-year **6:**1190
Mars (planet) **6:**1228
Mercury (planet) **7:**1250
Meteor and meteorite **7:**1262
Moon **7:**1294
Nebula **7:**1327
Neptune (planet) **7:**1330
Neutron star **7:**1339
Nova **7:**1359
Orbit **7:**1426
Pluto (planet) **8:**1539
Quasar **8:**1609
Radio astronomy **8:**1633
Red giant **9:**1653
Redshift **9:**1654
Satellite **9:**1707
Saturn (planet) **9:**1708
Seasons **9:**1726
Solar system **9:**1762
Space **9:**1776
Spacecraft, manned **9:**1777
Space probe **9:**1783
Space station, international **9:**1788
Star **9:**1801
Starburst galaxy **9:**1806
Star cluster **9:**1808
Stellar magnetic fields **9:**1820
Sun **10:**1844
Supernova **10:**1852
Telescope **10:**1869
Ultraviolet astronomy **10:**1943
Uranus (planet) **10:**1952
Variable star **10:**1963
Venus (planet) **10:**1964
White dwarf **10:**2027
X-ray astronomy **10:**2038

Astrophysics

Astrophysics **1:**207
Big bang theory **2:**273
Binary star **2:**276
Black hole **2:**322
Brown dwarf **2:**358
Celestial mechanics **3:**423
Cosmic ray **3:**571
Cosmology **3:**574
Dark matter **4:**613
Galaxy **5:**941
Gamma ray **5:**949
Gamma-ray burst **5:**952
Gravity and gravitation **5:**1012
Infrared astronomy **6:**1100
International Ultraviolet Explorer **6:**1120
Interstellar matter **6:**1130
Light-year **6:**1190
Neutron star **7:**1339
Orbit **7:**1426
Quasar **8:**1609
Radio astronomy **8:**1633
Red giant **9:**1653
Redshift **9:**1654
Space **9:**1776
Star **9:**1801
Starburst galaxy **9:**1806
Star cluster **9:**1808
Stellar magnetic fields **9:**1820
Sun **10:**1844

Supernova	**10:**1852
Ultraviolet astronomy	**10:**1943
Uranus (planet)	**10:**1952
Variable star	**10:**1963
White dwarf	**10:**2027
X-ray astronomy	**10:**2038

Atomic/Nuclear physics

Actinides	**1:**23
Alkali metals	**1:**99
Alkali earth metals	**1:**102
Alternative energy sources	**1:**111
Antiparticle	**1:**163
Atom	**2:**226
Atomic mass	**2:**229
Atomic theory	**2:**232
Chemical bond	**3:**453
Dating techniques	**4:**616
Electron	**4:**768
Half-life	**6:**1027
Ionization	**6:**1135
Isotope	**6:**1141
Lanthanides	**6:**1163
Mole (measurement)	**7:**1282
Molecule	**7:**1285
Neutron	**7:**1337
Noble gases	**7:**1349
Nuclear fission	**7:**1361
Nuclear fusion	**7:**1366
Nuclear medicine	**7:**1372
Nuclear power	**7:**1374
Nuclear weapons	**7:**1381
Particle accelerators	**8:**1475
Quantum mechanics	**8:**1607
Radiation	**8:**1619
Radiation exposure	**8:**1621
Radiology	**8:**1637
Subatomic particles	**10:**1829
X ray	**10:**2033

Automotive engineering

Automobile	**2:**245
Diesel engine	**4:**646
Internal-combustion engine	**6:**1117

Bacteriology

Bacteria	**2:**253
Biological warfare	**2:**287
Disease	**4:**669
Legionnaire's disease	**6:**1179

Ballistics

Ballistics	**2:**260
Nuclear weapons	**7:**1381
Rockets and missiles	**9:**1693

Biochemistry

Amino acid	**1:**130
Biochemistry	**2:**279
Carbohydrate	**2:**387
Cell	**3:**428
Cholesterol	**3:**469
Enzyme	**5:**812
Fermentation	**5:**864
Hormones	**6:**1050
Human Genome Project	**6:**1060
Lipids	**6:**1191
Metabolism	**7:**1255
Nucleic acid	**7:**1387
Osmosis	**7:**1436
Photosynthesis	**8:**1505
Proteins	**8:**1586
Respiration	**9:**1672
Vitamin	**10:**1981
Yeast	**10:**2043

Biology

Adaptation **1:**26
Algae **1:**91
Amino acid **1:**130
Amoeba **1:**131
Amphibians **1:**134
Anatomy **1:**138
Animal **1:**145
Antibody and antigen **1:**159
Arachnids **1:**168
Arthropods **1:**183
Bacteria **2:**253
Behavior **2:**270
Biochemistry **2:**279
Biodegradable **2:**280
Biodiversity **2:**281
Biological warfare **2:**287
Biology **2:**290
Biome **2:**293
Biophysics **2:**302
Biosphere **2:**304
Biotechnology **2:**309
Birds **2:**312
Birth **2:**315
Birth defects **2:**319
Blood **2:**326
Botany **2:**334
Brain **2:**337
Butterflies **2:**364
Canines **2:**382
Carbohydrate **2:**387
Carcinogen **2:**406
Cell **3:**428
Cellulose **3:**442
Cetaceans **3:**448
Cholesterol **3:**469
Chromosome **3:**472
Circulatory system **3:**480
Clone and cloning **3:**484
Cockroaches **3:**505
Coelacanth **3:**508
Contraception **3:**562
Coral **3:**566
Crustaceans **3:**590
Cryobiology **3:**593
Digestive system **4:**653
Dinosaur **4:**658
Disease **4:**669
Ear **4:**693
Embryo and embryonic development **4:**785
Endocrine system **5:**796
Enzyme **5:**812
Eutrophication **5:**828
Evolution **5:**832
Excretory system **5:**839
Eye **5:**848
Felines **5:**855
Fermentation **5:**864
Fertilization **5:**867
Fish **5:**875
Flower **5:**878
Forestry **5:**901
Forests **5:**907
Fungi **5:**930
Genetic disorders **5:**966
Genetic engineering **5:**973
Genetics **5:**980
Heart **6:**1037
Hibernation **6:**1046
Hormones **6:**1050
Horticulture **6:**1053
Human Genome Project **6:**1060
Human evolution **6:**1054
Immune system **6:**1082
Indicator species **6:**1090
Insects **6:**1103
Integumentary system **6:**1109
Invertebrates **6:**1133
Kangaroos and wallabies **6:**1153
Leaf **6:**1172
Lipids **6:**1191
Lymphatic system **6:**1198
Mammals **6:**1222

Mendelian laws of inheritance 7:1246
Metabolism 7:1255
Metamorphosis 7:1259
Migration (animals) 7:1271
Molecular biology 7:1283
Mollusks 7:1288
Muscular system 7:1309
Mutation 7:1314
Nervous system 7:1333
Nucleic acid 7:1387
Osmosis 7:1436
Parasites 8:1467
Photosynthesis 8:1505
Phototropism 8:1508
Physiology 8:1516
Plague 8:1518
Plankton 8:1520
Plant 8:1522
Primates 8:1571
Proteins 8:1586
Protozoa 8:1590
Puberty 8:1599
Rain forest 8:1641
Reproduction 9:1664
Reproductive system 9:1667
Reptiles 9:1670
Respiration 9:1672
Respiratory system 9:1677
Rh factor 9:1683
Seed 9:1729
Sexually transmitted diseases 9:1735
Skeletal system 9:1739
Smell 9:1750
Snakes 9:1752
Speech 9:1796
Sponges 9:1799
Taste 10:1861
Touch 10:1903
Tree 10:1927
Tumor 10:1934
Vaccine 10:1957
Vertebrates 10:1967
Virus 10:1974
Vitamin 10:1981
Wetlands 10:2024
Yeast 10:2043

Biomedical engineering

Electrocardiogram 4:751
Radiology 8:1637

Biotechnology

Biotechnology 2:309
Brewing 2:352
Fermentation 5:864
Vaccine 10:1957

Botany

Botany 2:334
Cellulose 3:442
Cocaine 3:501
Cotton 3:577
Flower 5:878
Forestry 5:901
Forests 5:907
Horticulture 6:1053
Leaf 6:1172
Marijuana 6:1224
Photosynthesis 8:1505
Phototropism 8:1508
Plant 8:1522
Seed 9:1729
Tree 10:1927

Cartography

Cartography 2:410
Geologic map 5:986

Cellular biology

Amino acid **1:**130
Carbohydrate **2:**387
Cell **3:**428
Cholesterol **3:**469
Chromosome **3:**472
Genetics **5:**980
Lipids **6:**1191
Osmosis **7:**1436
Proteins **8:**1586

Chemistry

Acids and bases **1:**14
Actinides **1:**23
Aerosols **1:**43
Agent Orange **1:**54
Agrochemical **1:**65
Alchemy **1:**82
Alcohols **1:**88
Alkali metals **1:**99
Alkaline earth metals **1:**102
Aluminum family **1:**122
Atom **2:**226
Atomic mass **2:**229
Atomic theory **2:**232
Biochemistry **2:**279
Carbon dioxide **2:**393
Carbon family **2:**395
Carbon monoxide **2:**403
Catalyst and catalysis **2:**413
Chemical bond **3:**453
Chemical w\arfare **3:**457
Chemistry **3:**463
Colloid **3:**515
Combustion **3:**522
Composite materials **3:**536
Compound, chemical **3:**541
Crystal **3:**601
Cyclamate **3:**608
DDT (dichlorodiphenyl-trichloroethane) **4:**619
Diffusion **4:**651
Dioxin **4:**667
Distillation **4:**675
Dyes and pigments **4:**686
Electrolysis **4:**755
Element, chemical **4:**774
Enzyme **5:**812
Equation, chemical **5:**815
Equilibrium, chemical **5:**817
Explosives **5:**843
Fermentation **5:**864
Filtration **5:**872
Formula, chemical **5:**914
Halogens **6:**1030
Hormones **6:**1050
Hydrogen **6:**1068
Industrial minerals **6:**1092
Ionization **6:**1135
Isotope **6:**1141
Lanthanides **6:**1163
Lipids **6:**1191
Metabolism **7:**1255
Mole (measurement) **7:**1282
Molecule **7:**1285
Nitrogen family **7:**1344
Noble gases **7:**1349
Nucleic acid **7:**1387
Osmosis **7:**1436
Oxidation-reduction reaction **7:**1439
Oxygen family **7:**1442
Ozone **7:**1450
Periodic table **8:**1486
pH **8:**1495
Photochemistry **8:**1498
Photosynthesis **8:**1505
Plastics **8:**1532
Poisons and toxins **8:**1542
Polymer **8:**1563
Proteins **8:**1586
Qualitative analysis **8:**1603
Quantitative analysis **8:**1604

Reaction, chemical 9:1647
Respiration 9:1672
Soaps and detergents 9:1756
Solution 9:1767
Transition elements 10:1913
Vitamin 10:1981
Yeast 10:2043

Civil engineering

Bridges 2:354
Canal 2:376
Dam 4:611
Lock 6:1192

Climatology

Global climate 5:1006
Ice ages 6:1075
Seasons 9:1726

Communications/ Graphic arts

Antenna 1:153
CAD/CAM 2:369
Cellular/digital technology 3:439
Compact disc 3:531
Computer software 3:549
DVD technology 4:684
Hologram and holography 6:1048
Internet 6:1123
Magnetic recording/ audiocassette 6:1209
Microwave communication 7: 1268
Petroglyphs and pictographs 8:1491
Photocopying 8:1499
Radio 8:1626
Satellite 9:1707
Telegraph 10:1863
Telephone 10:1866
Television 10:1875
Video recording 10:1968

Computer science

Artificial intelligence 1:188
Automation 2:242
CAD/CAM 2:369
Calculator 2:370
Cellular/digital technology 3:439
Compact disc 3:531
Computer, analog 3:546
Computer, digital 3:547
Computer software 3:549
Internet 6:1123
Mass production 7:1236
Robotics 9:1690
Virtual reality 10:1969

Cosmology

Astrophysics 1:207
Big Bang theory 2:273
Cosmology 3:574
Galaxy 5:941
Space 9:1776

Cryogenics

Cryobiology 3:593
Cryogenics 3:595

Dentistry

Dentistry 4:626
Fluoridation 5:889

Ecology/Environmental science

Acid rain 1:9
Alternative energy sources 1:111
Biodegradable 2:280
Biodiversity 2:281

Bioenergy **2:**284
Biome **2:**293
Biosphere **2:**304
Carbon cycle **2:**389
Composting **3:**539
DDT (dichlorodiphenyl-trichloroethane) **4:**619
Desert **4:**634
Dioxin **4:**667
Drift net **4:**680
Drought **4:**682
Ecology **4:**725
Ecosystem **4:**728
Endangered species **5:**793
Environmental ethics **5:**807
Erosion **5:**820
Eutrophication **5:**828
Food web and food chain **5:**894
Forestry **5:**901
Forests **5:**907
Gaia hypothesis **5:**935
Greenhouse effect **5:**1016
Hydrologic cycle **6:**1071
Indicator species **6:**1090
Nitrogen cycle **7:**1342
Oil spills **7:**1422
Organic farming **7:**1431
Paleoecology **8:**1457
Pollution **8:**1549
Pollution control **8:**1558
Rain forest **8:**1641
Recycling **9:**1650
Succession **10:**1837
Waste management **10:**2003
Wetlands **10:**2024

Electrical engineering

Antenna **1:**153
Battery **2:**268
Cathode **3:**415
Cathode-ray tube **3:**417
Cell, electrochemical **3:**436
Compact disc **3:**531
Diode **4:**665
Electric arc **4:**734
Electric current **4:**737
Electricity **4:**741
Electric motor **4:**747
Electrocardiogram **4:**751
Electromagnetic field **4:**758
Electromagnetic induction **4:**760
Electromagnetism **4:**766
Electronics **4:**773
Fluorescent light **5:**886
Generator **5:**962
Incandescent light **6:**1087
Integrated circuit **6:**1106
LED (light-emitting diode) **6:** 1176
Magnetic recording/audiocassette **6:**1209
Radar **8:**1613
Radio **8:**1626
Superconductor **10:**1849
Telegraph **10:**1863
Telephone **10:**1866
Television **10:**1875
Transformer **10:**1908
Transistor **10:**1910
Ultrasonics **10:**1941
Video recording **10:**1968

Electronics

Antenna **1:**153
Battery **2:**268
Cathode **3:**415
Cathode-ray tube **3:**417
Cell, electrochemical **3:**436
Compact disc **3:**531
Diode **4:**665
Electric arc **4:**734
Electric current **4:**737
Electricity **4:**741
Electric motor **4:**747

Electromagnetic field **4:**758
Electromagnetic induction **4:**760
Electronics **4:**773
Generator **5:**962
Integrated circuit **6:**1106
LED (light-emitting diode) **6:**1176
Magnetic recording/ audiocassette **6:**1209
Radar **8:**1613
Radio **8:**1626
Superconductor **10:**1849
Telephone **10:**1866
Television **10:**1875
Transformer **10:**1908
Transistor **10:**1910
Ultrasonics **10:**1941
Video recording **10:**1968

Embryology

Embryo and embryonic development **4:**785
Fertilization **5:**867
Reproduction **9:**1664
Reproductive system **9:**1667

Engineering

Aerodynamics **1:**39
Aircraft **1:**74
Antenna **1:**153
Automation **2:**242
Automobile **2:**245
Balloon **1:**261
Battery **2:**268
Bridges **2:**354
Canal **2:**376
Cathode **3:**415
Cathode-ray tube **3:**417
Cell, electrochemical **3:**436
Compact disc **3:**531
Dam **4:**611
Diesel engine **4:**646
Diode **4:**665
Electric arc **4:**734
Electric current **4:**737
Electric motor **4:**747
Electricity **4:**741
Electrocardiogram **4:**751
Electromagnetic field **4:**758
Electromagnetic induction **4:**760
Electromagnetism **4:**766
Electronics **4:**773
Engineering **5:**805
Fluorescent light **5:**886
Generator **5:**962
Incandescent light **6:**1087
Integrated circuit **6:**1106
Internal-combustion engine **6:**1117
Jet engine **6:**1143
LED (light-emitting diode) **6:** 1176
Lock **6:**1192
Machines, simple **6:**1203
Magnetic recording/ audiocassette **6:**1209
Mass production **7:**1236
Radar **8:**1613
Radio **8:**1626
Steam engine **9:**1817
Submarine **10:**1834
Superconductor **10:**1849
Telegraph **10:**1863
Telephone **10:**1866
Television **10:**1875
Transformer **10:**1908
Transistor **10:**1910
Ultrasonics **10:**1941
Video recording **10:**1968

Entomology

Arachnids **1:**168
Arthropods **1:**183

Butterflies **2:**364
Cockroaches **3:**505
Insects **6:**1103
Invertebrates **6:**1133
Metamorphosis **7:**1259

Epidemiology

Biological warfare **2:**287
Disease **4:**669
Ebola virus **4:**717
Plague **8:**1518
Poliomyelitis **8:**1546
Sexually transmitted diseases **9:**1735
Vaccine **10:**1957

Evolutionary biology

Adaptation **1:**26
Evolution **5:**832
Human evolution **6:**1054
Mendelian laws of inheritance **7:**1246

Food science

Brewing **2:**352
Cyclamate **3:**608
Food preservation **5:**890
Nutrition **7:**1399

Forensic science

Forensic science **5:**898

Forestry

Forestry **5:**901
Forests **5:**907
Rain forest **8:**1641
Tree **10:**1927

General science

Alchemy **1:**82
Chaos theory **3:**451
Metric system **7:**1265
Scientific method **9:**1722
Units and standards **10:**1948

Genetic engineering

Biological warfare **2:**287
Biotechnology **2:**309
Clone and cloning **3:**484
Genetic engineering **5:**973

Genetics

Biotechnology **2:**309
Birth defects **2:**319
Cancer **2:**379
Carcinogen **2:**406
Chromosome **3:**472
Clone and cloning **3:**484
Genetic disorders **5:**966
Genetic engineering **5:**973
Genetics **5:**980
Human Genome Project **6:**1060
Mendelian laws of inheritance **7:**1246
Mutation **7:**1314
Nucleic acid **7:**1387

Geochemistry

Coal **3:**492
Earth (planet) **4:**698
Earth science **4:**707
Earth's interior **4:**708
Glacier **5:**1000
Minerals **7:**1273
Rocks **9:**1701
Soil **9:**1758

Geography

Africa **1:**49
Antarctica **1:**147
Asia **1:**194
Australia **2:**238
Biome **2:**293
Cartography **2:**410
Coast and beach **3:**498
Desert **4:**634
Europe **5:**823
Geologic map **5:**986
Island **6:**1137
Lake **6:**1159
Mountain **7:**1301
North America **7:**1352
River **9:**1685
South America **9:**1772

Geology

Catastrophism **3:**415
Cave **3:**420
Coal **3:**492
Coast and beach **3:**498
Continental margin **3:**560
Dating techniques **4:**616
Desert **4:**634
Earthquake **4:**702
Earth science **4:**707
Earth's interior **4:**708
Erosion **5:**820
Fault **5:**855
Geologic map **5:**986
Geologic time **5:**990
Geology **5:**993
Glacier **5:**1000
Hydrologic cycle **6:**1071
Ice ages **6:**1075
Iceberg **6:**1078
Industrial minerals **6:**1092
Island **6:**1137
Lake **6:**1159
Minerals **7:**1273
Mining **7:**1278
Mountain **7:**1301
Natural gas **7:**1319
Oil drilling **7:**1418
Oil spills **7:**1422
Petroleum **8:**1492
Plate tectonics **8:**1534
River **9:**1685
Rocks **9:**1701
Soil **9:**1758
Uniformitarianism **10:**1946
Volcano **10:**1992
Water **10:**2010

Geophysics

Earth (planet) **4:**698
Earth science **4:**707
Fault **5:**855
Plate tectonics **8:**1534

Gerontology

Aging and death **1:**59
Alzheimer's disease **1:**126
Arthritis **1:**181
Dementia **4:**622
Gerontology **5:**999

Gynecology

Contraception **3:**562
Fertilization **5:**867
Gynecology **5:**1022
Puberty **8:**1599
Reproduction **9:**1664

Health/Medicine

Acetylsalicylic acid **1:**6
Addiction **1:**32
Attention-deficit hyperactivity disorder (ADHD) **2:**237

Depression **4:**630
AIDS (acquired immunodeficiency syndrome) **1:**70
Alcoholism **1:**85
Allergy **1:**106
Alternative medicine **1:**118
Alzheimer's disease **1:**126
Amino acid **1:**130
Anesthesia **1:**142
Antibiotics **1:**155
Antiseptics **1:**164
Arthritis **1:**181
Asthma **1:**204
Attention-deficit hyperactivity disorder (ADHD) **2:**237
Birth defects **2:**319
Blood supply **2:**330
Burn **2:**361
Carcinogen **2:**406
Carpal tunnel syndrome **2:**408
Cholesterol **3:**469
Cigarette smoke **3:**476
Cocaine **3:**501
Contraception **3:**562
Dementia **4:**622
Dentistry **4:**626
Depression **4:**630
Diabetes mellitus **4:**638
Diagnosis **4:**640
Dialysis **4:**644
Disease **4:**669
Dyslexia **4:**690
Eating disorders **4:**711
Ebola virus **4:**717
Electrocardiogram **4:**751
Fluoridation **5:**889
Food preservation **5:**890
Genetic disorders **5:**966
Genetic engineering **5:**973
Genetics **5:**980
Gerontology **5:**999
Gynecology **5:**1022
Hallucinogens **6:**1027
Immune system **6:**1082
Legionnaire's disease **6:**1179
Lipids **6:**1191
Malnutrition **6:**1216
Marijuana **6:**1224
Multiple personality disorder **7:**1305
Nuclear medicine **7:**1372
Nutrition **7:**1399
Obsession **7:**1405
Orthopedics **7:**1434
Parasites **8:**1467
Phobia **8:**1497
Physical therapy **8:**1511
Plague **8:**1518
Plastic surgery **8:**1527
Poliomyelitis **8:**1546
Prosthetics **8:**1579
Protease inhibitor **8:**1583
Psychiatry **8:**1592
Psychology **8:**1594
Psychosis **8:**1596
Puberty **8:**1599
Radial keratotomy **8:**1615
Radiology **8:**1637
Rh factor **9:**1683
Schizophrenia **9:**1716
Sexually transmitted diseases **9:**1735
Sleep and sleep disorders **9:**1745
Stress **9:**1826
Sudden infant death syndrome (SIDS) **10:**1840
Surgery **10:**1855
Tranquilizers **10:**1905
Transplant, surgical **10:**1923
Tumor **10:**1934
Vaccine **10:**1957
Virus **10:**1974
Vitamin **10:**1981
Vivisection **10:**1989

Horticulture

Horticulture **6:**1053
Plant **8:**1522
Seed **9:**1729
Tree **10:**1927

Immunology

Allergy **1:**106
Antibiotics **1:**155
Antibody and antigen **1:**159
Immune system **6:**1082
Vaccine **10:**1957

Marine biology

Algae **1:**91
Amphibians **1:**134
Cetaceans **3:**448
Coral **3:**566
Crustaceans **3:**590
Endangered species **5:**793
Fish **5:**875
Mammals **6:**1222
Mollusks **7:**1288
Ocean zones **7:**1414
Plankton **8:**1520
Sponges **9:**1799
Vertebrates **10:**1967

Materials science

Abrasives **1:**2
Adhesives **1:**37
Aerosols **1:**43
Alcohols **1:**88
Alkaline earth metals **1:**102
Alloy **1:**110
Aluminum family **1:**122
Artificial fibers **1:**186
Asbestos **1:**191
Biodegradable **2:**280
Carbon family **2:**395
Ceramic **3:**447
Composite materials **3:**536
Dyes and pigments **4:**686
Electrical conductivity **4:**731
Electrolysis **4:**755
Expansion, thermal **5:**842
Fiber optics **5:**870
Glass **5:**1004
Halogens **6:**1030
Hand tools **6:**1036
Hydrogen **6:**1068
Industrial minerals **6:**1092
Minerals **7:**1273
Nitrogen family **7:**1344
Oxygen family **7:**1442
Plastics **8:**1532
Polymer **8:**1563
Soaps and detergents **9:**1756
Superconductor **10:**1849
Transition elements **10:**1913

Mathematics

Abacus **1:**1
Algebra **1:**97
Arithmetic **1:**177
Boolean algebra **2:**333
Calculus **2:**371
Chaos theory **3:**451
Circle **3:**478
Complex numbers **3:**534
Correlation **3:**569
Fractal **5:**921
Fraction, common **5:**923
Function **5:**927
Game theory **5:**945
Geometry **5:**995
Graphs and graphing **5:**1009
Imaginary number **6:**1081
Logarithm **6:**1195
Mathematics **7:**1241

Multiplication **7:**1307
Natural numbers **7:**1321
Number theory **7:**1393
Numeration systems **7:**1395
Polygon **8:**1562
Probability theory **8:**1575
Proof (mathematics) **8:**1578
Pythagorean theorem **8:**1601
Set theory **9:**1733
Statistics **9:**1810
Symbolic logic **10:**1859
Topology **10:**1897
Trigonometry **10:**1931
Zero **10:**2047

Metallurgy

Alkali metals **1:**99
Alkaline earth metals **1:**102
Alloy **1:**110
Aluminum family **1:**122
Carbon family **2:**395
Composite materials **3:**536
Industrial minerals **6:**1092
Minerals **7:**1273
Mining **7:**1278
Precious metals **8:**1566
Transition elements **10:**1913

Meteorology

Air masses and fronts **1:**80
Atmosphere, composition and structure **2:**211
Atmosphere observation **2:**215
Atmospheric circulation **2:**218
Atmospheric optical effects **2:**221
Atmospheric pressure **2:**225
Barometer **2:**265
Clouds **3:**490
Cyclone and anticyclone **3:**608
Drought **4:**682
El Niño **4:**782
Global climate **5:**1006
Monsoon **7:**1291
Ozone **7:**1450
Storm surge **9:**1823
Thunderstorm **10:**1887
Tornado **10:**1900
Weather **10:**2017
Weather forecasting **10:**2020
Wind **10:**2028

Microbiology

Algae **1:**91
Amoeba **1:**131
Antiseptics **1:**164
Bacteria **2:**253
Biodegradable **2:**280
Biological warfare **2:**287
Composting **3:**539
Parasites **8:**1467
Plankton **8:**1520
Protozoa **8:**1590
Yeast **10:**2043

Mineralogy

Abrasives **1:**2
Ceramic **3:**447
Industrial minerals **6:**1092
Minerals **7:**1273
Mining **7:**1278

Molecular biology

Amino acid **1:**130
Antibody and antigen **1:**159
Biochemistry **2:**279
Birth defects **2:**319
Chromosome **3:**472
Clone and cloning **3:**484
Enzyme **5:**812
Genetic disorders **5:**966

Genetic engineering **5:**973
Genetics **5:**980
Hormones **6:**1050
Human Genome Project **6:**1060
Lipids **6:**1191
Molecular biology **7:**1283
Mutation **7:**1314
Nucleic acid **7:**1387
Proteins **8:**1586

Mycology

Brewing **2:**352
Fermentation **5:**864
Fungi **5:**930
Yeast **10:**2043

Nutrition

Diabetes mellitus **4:**638
Eating disorders **4:**711
Food web and food chain **5:**894
Malnutrition **6:**1216
Nutrition **7:**1399
Vitamin **10:**1981

Obstetrics

Birth **2:**315
Birth defects **2:**319
Embryo and embryonic development **4:**785

Oceanography

Continental margin **3:**560
Currents, ocean **3:**604
Ocean **7:**1407
Oceanography **7:**1411
Ocean zones **7:**1414
Tides **10:**1890

Oncology

Cancer **2:**379
Disease **4:**669
Tumor **10:**1934

Ophthalmology

Eye **5:**848
Lens **6:**1184
Radial keratotomy **8:**1615

Optics

Atmospheric optical effects **2:**221
Compact disc **3:**531
Diffraction **4:**648
Eye **5:**848
Fiber optics **5:**870
Hologram and holography **6:**1048
Laser **6:**1166
LED (light-emitting diode) **6:**1176
Lens **6:**1184
Light **6:**1185
Luminescence **6:**1196
Photochemistry **8:**1498
Photocopying **8:**1499
Telescope **10:**1869
Television **10:**1875
Video recording **10:**1968

Organic chemistry

Carbon family **2:**395
Coal **3:**492
Cyclamate **3:**608
Dioxin **4:**667
Fermentation **5:**864
Hydrogen **6:**1068
Hydrologic cycle **6:**1071
Lipids **6:**1191

Natural gas **7:**1319
Nitrogen cycle **7:**1342
Nitrogen family **7:**1344
Oil spills **7:**1422
Organic chemistry **7:**1428
Oxygen family **7:**1442
Ozone **7:**1450
Petroleum **8:**1492
Vitamin **10:**1981

Orthopedics

Arthritis **1:**181
Orthopedics **7:**1434
Prosthetics **8:**1579
Skeletal system **9:**1739

Paleontology

Dating techniques **4:**616
Dinosaur **4:**658
Evolution **5:**832
Fossil and fossilization **5:**917
Human evolution **6:**1054
Paleoecology **8:**1457
Paleontology **8:**1459

Parasitology

Amoeba **1:**131
Disease **4:**669
Fungi **5:**930
Parasites **8:**1467

Pathology

AIDS (acquired immunodeficiency syndrome) **1:**70
Alzheimer's disease **1:**126
Arthritis **1:**181
Asthma **1:**204
Attention-deficit hyperactivity disorder (ADHD) **2:**237
Bacteria **2:**253
Biological warfare **2:**287
Cancer **2:**379
Dementia **4:**622
Diabetes mellitus **4:**638
Diagnosis **4:**640
Dioxin **4:**667
Disease **4:**669
Ebola virus **4:**717
Genetic disorders **5:**966
Malnutrition **6:**1216
Orthopedics **7:**1434
Parasites **8:**1467
Plague **8:**1518
Poliomyelitis **8:**1546
Sexually transmitted diseases **9:**1735
Tumor **10:**1934
Vaccine **10:**1957
Virus **10:**1974

Pharmacology

Acetylsalicylic acid **1:**6
Antibiotics **1:**155
Antiseptics **1:**164
Cocaine **3:**501
Hallucinogens **6:**1027
Marijuana **6:**1224
Poisons and toxins **8:**1542
Tranquilizers **10:**1905

Physics

Acceleration **1:**4
Acoustics **1:**17
Aerodynamics **1:**39
Antiparticle **1:**163
Astrophysics **1:**207
Atom **2:**226
Atomic mass **2:**229
Atomic theory **2:**232
Ballistics **2:**260

Battery **2:**268
Biophysics **2:**302
Buoyancy **2:**360
Calorie **2:**375
Cathode **3:**415
Cathode-ray tube **3:**417
Celestial mechanics **3:**423
Cell, electrochemical **3:**436
Chaos theory **3:**451
Color **3:**518
Combustion **3:**522
Conservation laws **3:**554
Coulomb **3:**579
Cryogenics **3:**595
Dating techniques **4:**616
Density **4:**624
Diffraction **4:**648
Diode **4:**665
Doppler effect **4:**677
Echolocation **4:**720
Elasticity **4:**730
Electrical conductivity **4:**731
Electric arc **4:**734
Electric current **4:**737
Electricity **4:**741
Electric motor **4:**747
Electrolysis **4:**755
Electromagnetic field **4:**758
Electromagnetic induction **4:**760
Electromagnetic spectrum **4:**763
Electromagnetism **4:**766
Electron **4:**768
Electronics **4:**773
Energy **5:**801
Evaporation **5:**831
Expansion, thermal **5:**842
Fiber optics **5:**870
Fluid dynamics **5:**882
Fluorescent light **5:**886
Frequency **5:**925
Friction **5:**926
Gases, liquefaction of **5:**955
Gases, properties of **5:**959
Generator **5:**962
Gravity and gravitation **5:**1012
Gyroscope **5:**1024
Half-life **6:**1027
Heat **6:**1043
Hologram and holography **6:**1048
Incandescent light **6:**1087
Integrated circuit **6:**1106
Interference **6:**1112
Interferometry **6:**1114
Ionization **6:**1135
Isotope **6:**1141
Laser **6:**1166
Laws of motion **6:**1169
LED (light-emitting diode) **6:**1176
Lens **6:**1184
Light **6:**1185
Luminescence **6:**1196
Magnetic recording/ audiocassette **6:**1209
Magnetism **6:**1212
Mass **7:**1235
Mass spectrometry **7:**1239
Matter, states of **7:**1243
Microwave communication **7:**1268
Molecule **7:**1285
Momentum **7:**1290
Nuclear fission **7:**1361
Nuclear fusion **7:**1366
Nuclear medicine **7:**1372
Nuclear power **7:**1374
Nuclear weapons **7:**1381
Particle accelerators **8:**1475
Periodic function **8:**1485
Photochemistry **8:**1498
Photoelectric effect **8:**1502
Physics **8:**1513
Pressure **8:**1570
Quantum mechanics **8:**1607
Radar **8:**1613
Radiation **8:**1619

Radiation exposure **8:**1621
Radio **8:**1626
Radioactive tracers **8:**1629
Radioactivity **8:**1630
Radiology **8:**1637
Relativity, theory of **9:**1659
Sonar **9:**1770
Spectroscopy **9:**1792
Spectrum **9:**1794
Subatomic particles **10:**1829
Superconductor **10:**1849
Telegraph **10:**1863
Telephone **10:**1866
Television **10:**1875
Temperature **10:**1879
Thermal expansion **5:**842
Thermodynamics **10:**1885
Time **10:**1894
Transformer **10:**1908
Transistor **10:**1910
Tunneling **10:**1937
Ultrasonics **10:**1941
Vacuum **10:**1960
Vacuum tube **10:**1961
Video recording **10:**1968
Virtual reality **10:**1969
Volume **10:**1999
Wave motion **10:**2014
X ray **10:**2033

Primatology

Animal **1:**145
Endangered species **5:**793
Mammals **6:**1222
Primates **8:**1571
Vertebrates **10:**1967

Psychiatry/Psychology

Addiction **1:**32
Alcoholism **1:**85
Attention-deficit hyperactivity disorder (ADHD) **2:**237
Behavior **2:**270
Cognition **3:**511
Depression **4:**630
Eating disorders **4:**711
Multiple personality disorder **7:**1305
Obsession **7:**1405
Perception **8:**1482
Phobia **8:**1497
Psychiatry **8:**1592
Psychology **8:**1594
Psychosis **8:**1596
Reinforcement, positive and negative **9:**1657
Savant **9:**1712
Schizophrenia **9:**1716
Sleep and sleep disorders **9:**1745
Stress **9:**1826

Radiology

Nuclear medicine **7:**1372
Radioactive tracers **8:**1629
Radiology **8:**1637
Ultrasonics **10:**1941
X ray **10:**2033

Robotics

Automation **2:**242
Mass production **7:**1236
Robotics **9:**1690

Seismology

Earthquake **4:**702
Volcano **10:**1992

Sociology

Adaptation **1:**26
Aging and death **1:**59

Alcoholism **1:**85
Behavior **2:**270
Gerontology **5:**999
Migration (animals) **7:**1271

Technology

Abrasives **1:**2
Adhesives **1:**37
Aerosols **1:**43
Aircraft **1:**74
Alloy **1:**110
Alternative energy sources **1:**111
Antenna **1:**153
Artificial fibers **1:**186
Artificial intelligence **1:**188
Asbestos **1:**191
Automation **2:**242
Automobile **2:**245
Balloon **1:**261
Battery **2:**268
Biotechnology **2:**309
Brewing **2:**352
Bridges **2:**354
CAD/CAM **2:**369
Calculator **2:**370
Canal **2:**376
Cathode **3:**415
Cathode-ray tube **3:**417
Cell, electrochemical **3:**436
Cellular/digital technology **3:**439
Centrifuge **3:**445
Ceramic **3:**447
Compact disc **3:**531
Computer, analog **3:**546
Computer, digital **3:**547
Computer software **3:**549
Cybernetics **3:**605
Dam **4:**611
Diesel engine **4:**646
Diode **4:**665
DVD technology **4:**684
Dyes and pigments **4:**686
Fiber optics **5:**870
Fluorescent light **5:**886
Food preservation **5:**890
Forensic science **5:**898
Generator **5:**962
Glass **5:**1004
Hand tools **6:**1036
Hologram and holography **6:**1048
Incandescent light **6:**1087
Industrial Revolution **6:**1097
Integrated circuit **6:**1106
Internal-combustion engine **6:**1117
Internet **6:**1123
Jet engine **6:**1143
Laser **6:**1166
LED (light-emitting diode) **6:**1176
Lens **6:**1184
Lock **6:**1192
Machines, simple **6:**1203
Magnetic recording/ audiocassette **6:**1209
Mass production **7:**1236
Mass spectrometry **7:**1239
Microwave communication **7:**1268
Paper **8:**1462
Photocopying **8:**1499
Plastics **8:**1532
Polymer **8:**1563
Prosthetics **8:**1579
Radar **8:**1613
Radio **8:**1626
Robotics **9:**1690
Rockets and missiles **9:**1693
Soaps and detergents **9:**1756
Sonar **9:**1770
Space station, international **9:**1788
Steam engine **9:**1817
Submarine **10:**1834
Superconductor **10:**1849
Telegraph **10:**1863
Telephone **10:**1866

Television **10:**1875
Transformer **10:**1908
Transistor **10:**1910
Vacuum tube **10:**1961
Video recording **10:**1968
Virtual reality **10:**1969

Virology

AIDS (acquired immuno-deficiency syndrome) **1:**70
Disease **4:**669
Ebola virus **4:**717
Plague **8:**1518
Poliomyelitis **8:**1546
Sexually transmitted diseases **9:**1735
Vaccine **10:**1957
Virus **10:**1974

Weaponry

Ballistics **2:**260
Biological warfare **2:**287
Chemical warfare **3:**457
Forensic science **5:**898
Nuclear weapons **7:**1381
Radar **8:**1613
Rockets and missiles **9:**1693

Wildlife conservation

Biodiversity **2:**281
Biome **2:**293
Biosphere **2:**304
Drift net **4:**680
Ecology **4:**725
Ecosystem **4:**728
Endangered species **5:**793
Forestry **5:**901
Gaia hypothesis **5:**935
Wetlands **10:**2024

Zoology

Amphibians **1:**134
Animal **1:**145
Arachnids **1:**168
Arthropods **1:**183
Behavior **2:**270
Birds **2:**312
Butterflies **2:**364
Canines **2:**382
Cetaceans **3:**448
Cockroaches **3:**505
Coelacanth **3:**508
Coral **3:**566
Crustaceans **3:**590
Dinosaur **4:**658
Echolocation **4:**720
Endangered species **5:**793
Felines **5:**855
Fish **5:**875
Hibernation **6:**1046
Indicator species **6:**1090
Insects **6:**1103
Invertebrates **6:**1133
Kangaroos and wallabies **6:**1153
Mammals **6:**1222
Metamorphosis **7:**1259
Migration (animals) **7:**1271
Mollusks **7:**1288
Plankton **8:**1520
Primates **8:**1571
Reptiles **9:**1670
Snakes **9:**1752
Sponges **9:**1799
Vertebrates **10:**1967

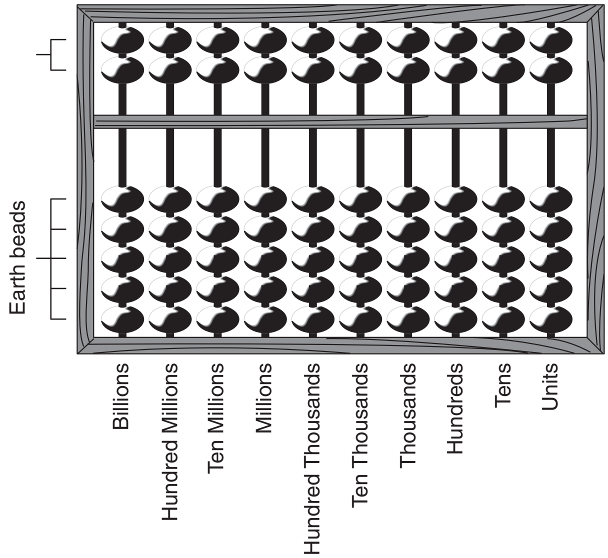
A

Abacus

The abacus is an ancient calculating machine. This simple apparatus is thought to have originated in Babylon about 5,000 years ago. Today, the abacus is still used commonly in Japan, China, the Middle East, and Russia. In China, the abacus is called a *suan pan,* meaning “counting tray.” In Japan, it is called a *soroban.* Japanese school children are still taught how to use the *soroban,* and competitions are held annually to find the most skillful calculators.

Historians think that the first abacus consisted of a shallow tray filled with fine sand or dust. Numbers were recorded and erased easily with a finger. The word abacus, in fact, may have come from the Semitic word for “dust,” *abq.*

A modern abacus is made of wood or plastic. It consists of a rectangular frame about the size of a shoe-box lid. Within the frame are at least nine vertical rods strung with moveable beads. A horizontal crossbar perpendicular to the rods separates the abacus into two unequal parts. The beads above the crossbar are known as heaven beads, and those below the crossbar are called earth beads.



On an abacus, the heaven beads have five times the value of the earth beads. *(Reproduced by permission of The Gale Group.)*

The numerical value of each bead depends on its location in the abacus. Each

heaven bead has a value of five times that of an earth bead below it. Each rod represents columns of written numbers. Beads on the vertical rod farthest to the right have their values multiplied by one. On this rod, each earth bead is one and each heaven bead is five. Beads on the second rod from the right, however, have their value multiplied by 10. On this rod, each earth bead represents 10 and each heaven bead stands for 50. Beads on the third rod from the right have their value multiplied by 100, so that each earth bead represents 100 and each heaven bead stands for 500, and so on.

To operate, an abacus is placed flat and all beads are pushed towards the outer edges, away from the crossbar. Beads are then slid upward or downward to represent a number. The number 7, for example, is represented by moving one heaven bead (worth 5) downward toward the crossbar and two earth beads (worth one each) upward toward the crossbar. The number 24 is represented by moving two earth beads on the second rod (worth 10 each) and four earth beads on the first rod (worth 1 each) upward. Addition, subtraction, and even lengthy multiplication and division problems can be solved with an abacus. Advanced users can even find the square root of any number.

[*See also* **Arithmetic; Mathematics**]

Abrasives

Abrasives are materials used to wear down, smooth, clean, shape, or polish a surface. The perfectly smooth surfaces needed in telescope mirrors, for example, are produced by grinding a piece of glass or metal with abrasives. One of the most familiar abrasives is sandpaper, heavy paper coated with a thin layer of aluminum oxide or silicon carbide. Sandpaper can be made in many grades, from coarse to very fine. The grade of sandpaper depends on the size of abrasive particles it contains.

Abrasives can be either natural or synthetic materials. Until the twentieth century, humans used naturally occurring materials, such as sandstone, quartz, emery, corundum, diamonds, and garnet, as abrasives. Then, in 1891, American inventor Edward G. Acheson (1856–1931) produced silicon carbide by heating a mixture of clay and coke. For 50 years, silicon carbide (also known as Carborundum™) was the second-hardest substance known, after diamond. This property made it popular as an abrasive. Other synthetic compounds, such as aluminum oxide, boron carbide, and boron nitride are also used now as abrasives.

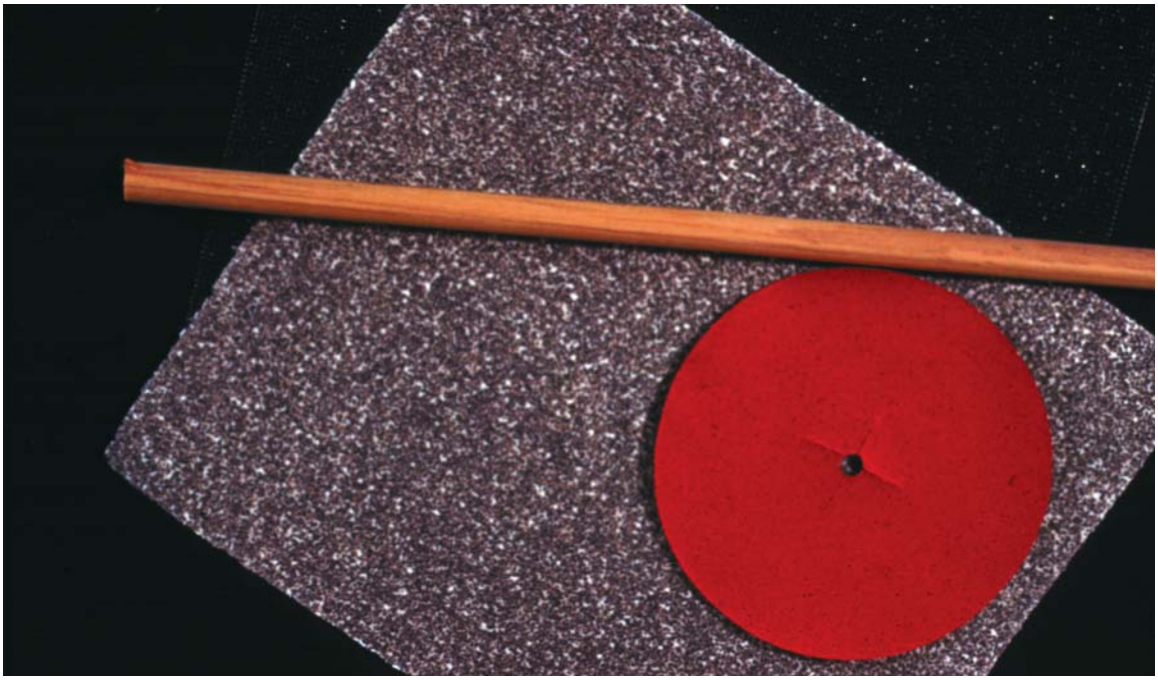
Mohs scale

A material can serve as an abrasive as long as it is harder than the material on which it is to be used. Diamond is the best abrasive of all because it is harder than all other substances. A measure of a material's hardness is the Mohs scale. This 0-to-10 scale was named after the German mineralogist who invented it in 1822, Friedrich Mohs (1773–1839). Any object listed on the Mohs scale can be used as an abrasive for any other object with a lower number. Aluminum oxide is a popular abrasive because it has a Mohs hardness of 9, higher than most other natural or synthetic objects.

Industrial applications of abrasives

Industry uses abrasives in three basic forms. They can be bonded to a material to form solid tools such as grinding wheels, cylinders, rings, cups, segments, or sticks. They can be attached to paper, cloth, plastic, or other material, as is done with sandpaper. Or they may be used in a loose form, as when a spray of sand is used to clean the surface of a building during sandblasting.

Most industrial applications of abrasives fall into one of four general categories. Cleaning involves the removal of dirt and imperfections



Sandpaper is a common abrasive. *(Reproduced by permission of Field Mark Publications.)*

from the surface of an object. One example is the use of grinding wheels to smooth off the surface of a metal. Shaping is the process by which an abrasive is used to produce a desired shape. Sharpening a tool is an example of shaping. Sizing is a kind of polishing in which an abrasive wears away a surface until it assumes some exact shape. Cutting is the separation of a material into two separate pieces, as when a diamond saw is used to cut through a piece of metal.

Acceleration

Acceleration is a measure of the rate at which the velocity of an object is changing. If you are riding in a car traveling in a straight line at a constant 50 kilometers per hour, you experience no acceleration because the car's velocity (rate of motion) is not changing. If the car begins to speed up, acceleration occurs because the car's velocity increases. If the car slows down, negative acceleration, or deceleration, occurs because the car's velocity decreases.

Acceleration and force

Our understanding of acceleration is due to the work of two great scientists, Italian physicist Galileo Galilei (1564–1642) and English physicist Isaac Newton (1642–1727). During the late sixteenth and early seventeenth centuries, Galileo first observed the motion of objects rolling down an inclined plane. He wrote mathematical equations that showed how the velocities of these objects increased as they rolled down the planes. These equations first described the idea of accelerated motion.

Some years later, Newton explained the observations made by Galileo. He said that the velocity of an object changes only when a force acts on that object. In the case of a ball rolling down a plane, that force is the force of gravity. Newton's discovery of the relationship between force and acceleration became one of the fundamental concepts in modern physics.

Linear acceleration

An object moving in a straight line is accelerated only if a force acts on it. For example, imagine a ball rolling across a smooth flat surface with a velocity of 5 meters per second. Then suppose someone hits the

Words to Know

Acceleration: The rate at which the velocity and/or direction of an object is changing with respect to time.

Circular acceleration: Acceleration in which the direction of motion is changing.

Force: A push or pull on an object that will accelerate an object.

Gravity: The special acceleration of 9.81 meters per second per second exerted by the attraction of the mass of Earth on nearby objects.

Linear acceleration: Acceleration in which the speed of an object is changing.

Velocity: The rate at which the position of an object changes with time, including both the speed and the direction.

ball lightly with a bat. The additional force on the ball provided by the bat will cause the ball to move faster.

Suppose that the ball's new velocity is 10 meters per second and that it takes 2 seconds to accelerate from its original velocity (5 meters per second) to its new velocity (10 meters per second). The acceleration of the ball, then, is the change in velocity of 5 meters per second (10 meters per second minus 5 meters per second) divided by the time it takes to increase in velocity (2 seconds), or 5 meters per second divided by 2 seconds. The acceleration is 2.5 meters per second per second. The unit of measurement used for acceleration—meters per second per second—may sound strange, but it tells by how much the velocity (meters per second) changes in each unit of time (per second).

Circular acceleration

The acceleration of an object depends on two factors, velocity and direction. An object that moves with constant speed but that changes direction is also accelerating. A car traveling around a curve in the road is accelerating even though its speed remains constant.

Another example of circular acceleration is the motion of the Moon around Earth. The Moon travels at a constant speed in its orbit. But it also

falls constantly towards Earth's surface. The force of Earth's gravity acts on the Moon not to change its speed but to change the direction in which it is traveling. Again, acceleration occurs when a force acts on an object.

[*See also* **Gravity and gravitation; Laws of motion; Particle accelerators**]

Acetylsalicylic acid

Acetylsalicylic (pronounced uh-SEE-tuhl-sa-luh-si-lik) acid, commonly known as aspirin, is the most popular therapeutic drug in the world. Sold without a prescription as tablets, capsules, powders, or suppositories (a meltable form for insertion into a body cavity), it reduces pain, fever, and swelling, is believed to decrease the risk of heart attacks and strokes, and may protect against colon cancer and help prevent premature birth. Aspirin is often called the wonder drug, but it can have some serious side effects: its use results in more accidental poisoning deaths in children under five years of age than any other drug.

History

In the mid- to late 1700s, English clergyman Edward Stone chewed on a piece of willow bark and discovered its analgesic (pain-killing) property after hearing an "old wives' tale" that declared a brew from the bark was "good for pain and whatever else ails you." The bark's active ingredient was isolated in 1827 and named salicin from the Greek word *salix,* meaning "willow." Salicylic acid was first produced from salicin in 1838. It was first produced synthetically (meaning produced in a lab from chemicals) from phenol (an acidic compound) in 1860. This synthetic product was effective in treating rheumatic fever and gout but caused burning of the throat and stomach upset. In 1897, a chemist named Felix Hoffmann, working at Bayer Laboratories in Germany, synthesized acetylsalicylic acid in a successful attempt to eliminate the side effects of salicylic acid.

Soon the process for making large quantities of acetylsalicylic acid was patented (allowing only the person or company who developed the product to manufacture or sell the product for a set number of years). Aspirin—named for its ingredients, acetyl and spiralic (salicylic) acid—became available by prescription. Its popularity was immediate and worldwide. Huge demand in the United States brought manufacture of aspirin to that country in 1915, when it also became available without a prescription.

Words to Know

Analgesic: Compound that relieves pain without inducing loss of consciousness.

Antipyretic: Anything that reduces fever.

Hypothalamus: A small area near the base of the brain where release of hormones influence such involuntary bodily functions as temperature, sexual behavior, sweating, heart rate, and moods.

Platelets: Irregularly shaped disks found in the blood of mammals that aid in clotting the blood.

Inflammation: The body's response to tissue damage, which includes pain, redness, swelling, and hotness of the affected area.

Prostaglandins: Groups of hormones and active substances produced by body tissue that regulate important bodily functions, such as blood pressure.

How it works

Analgesic/anti-inflammatory action. Aspirin is commonly used to relieve pain and reduce inflammation, the body's local response to any event causing tissue damage, which includes pain, redness, swelling, and hotness of the affected area. It works best against pain that is bearable; extreme pain is almost entirely unaffected, as is pain in internal organs. Aspirin blocks the production of hormones (chemical messengers formed by the body) called prostaglandins, which are often released by an injured cell. Prostaglandins in turn trigger the release of two other hormones that make nerves sensitive to pain. Aspirin's blocking action prevents this response and therefore is believed to prevent tissue inflammation. Remarkably, aspirin only acts on cells producing prostaglandins (for instance, injured cells). The effect of each dose lasts approximately four hours.

Antipyretic action. Aspirin's antipyretic (fever-reducing) action is believed to occur at the anterior (frontal) hypothalamus, a portion of the brain that regulates such functions as heart rate and body temperature. The body naturally reduces its heat through perspiration and the dilation (expansion) of blood vessels. Prostaglandins released in the hypothalamus inhibit the body's natural heat-reducing mechanism. As aspirin blocks

these prostaglandins, the hypothalamus is freed up to regulate body temperature.

Blood-thinning action. One prostaglandin, thromboxane A_2, aids platelet accumulation. (Platelets are cells involved in the clotting of blood.) Aspirin inhibits thromboxane production, thus "thinning" the blood. It is frequently prescribed in low doses over long periods for at-risk patients to help prevent blood clots that can result in heart attacks and strokes.

Adverse effects

Poisoning. Because aspirin is easily available and is present in many prescription and nonprescription medications, the risk of accidental overdose is relatively high. Children and the elderly are particularly susceptible, as their toxicity thresholds (the point at which the body reacts to a drug dosage as poison) are much lower than average adults. About 10 percent of all accidental or suicidal poisoning episodes reported by hospitals are related to aspirin.

Bleeding. As aspirin slows down platelet accumulation, its use increases risk of bleeding, a particular concern during surgery and childbirth. Aspirin's irritant effect on the stomach lining may cause internal bleeding, sometimes resulting in anemia (a condition in which blood does not have enough red blood cells or hemoglobin to carry a normal amount of oxygen).

Acetylsalicylic acid, commonly known as aspirin. *(Reproduced by permission of Field Mark Publications.)*

Reye's syndrome. Reye's syndrome is an extremely rare disease, usually striking children and teenagers between the ages of three and fifteen who are recovering from a viral infection, such as influenza or chicken pox. Reye's syndrome is characterized by severe vomiting, seizures, and confusion as well as swelling of the brain and the collection of fatty deposits in the liver. If left untreated, the disease can result in coma, permanent brain damage, or death. The cause of Reye's is unknown, but the onset is strongly associated with the treatment of viral infections with aspirin. Incidents of Reye's in children on aspirin therapy for chronic arthritis is significant. In 1985, these observations were widely publicized, and warning labels were placed on all aspirin medications. This resulted in a decline in the number

of children with viruses being treated with aspirin and a corresponding decline in cases of Reye's.

Other adverse effects. Aspirin can adversely affect breathing in people with nasal polyps or asthma, and its long-term use may cause kidney cancer or liver disease. There is some evidence that aspirin can delay the onset of labor in full-term pregnancies and, because it crosses the placenta (the organ that provides nourishment to the fetus), may be harmful to the fetus.

Acid rain

Acid rain is a popular phrase used to describe rain, snow, fog, or other precipitation that is full of acids that collect in the atmosphere due to the burning of fuels such as coal, petroleum, and gasoline. Acid rain was first recognized in Europe in the late 1800s but did not come to widespread public attention until about 1970, when its harmful effects on the environment were publicized. Research has shown that in many parts of the world, lakes, streams, and soils have become increasingly acidic, prompting a corresponding decline in fish populations.

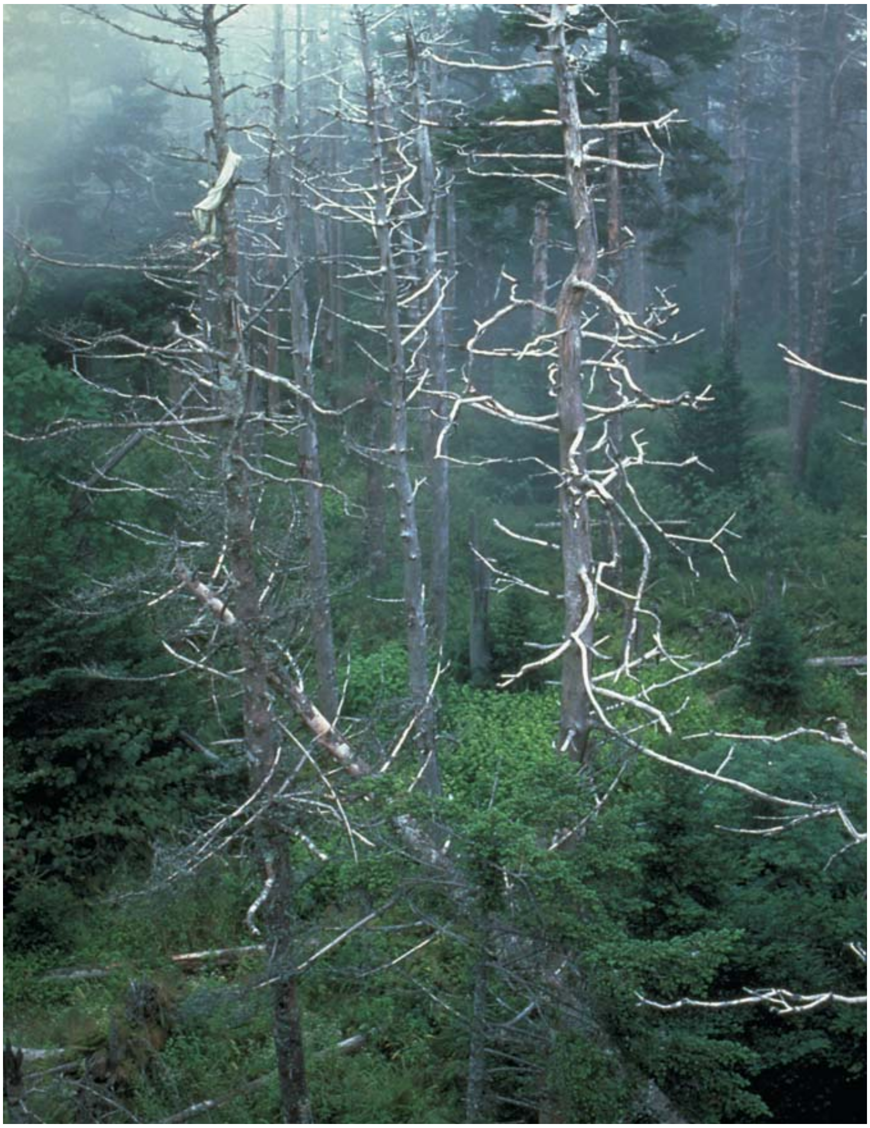
Acid rain occurs when polluted gases become trapped in clouds that drift for hundreds—even thousands—of miles and are finally released as acidic precipitation. Trees, lakes, animals, and even buildings are vulnerable to the slow, corrosive (wearing away) effects of acid rain.

Acid deposition

Acidification (the process of making acid) is not just caused by deposits of acidic rain but also by chemicals in snow and fog and by gases and particulates (small particles) when precipitation is not occurring.

The major human-made causes of acid deposition are (1) emissions of sulfur dioxide from power plants that burn coal and oil and (2) emissions of nitrogen oxides from automobiles. These emissions are transformed into sulfuric acid and nitric acid in the atmosphere, where they accumulate in cloud droplets and fall to Earth in rain and snow. (This is called wet deposition.) Other sources of acid deposition are gases like sulfur dioxide and nitrogen oxides, as well as very small particulates (such as ammonium sulfate and ammonium nitrate). These gases and particulates are usually deposited when it is not raining or snowing. (This is called dry deposition.)

Areas affected by acid deposition. Large areas of Europe and North America are exposed to these acidifying depositions. However, only certain types of ecosystems (all the animals, plants, and bacteria that make up a particular community living in a certain environment) are affected by these depositions. The most vulnerable ecosystems usually have a thin cover of soil, containing little calcium and sitting upon solid rock made up of hard minerals such as granite or quartz. Many freshwater lakes, streams, and rivers have become acidic, resulting in the decline or local



Trees killed by acid rain in the Great Smoky Mountains. *(Reproduced by permission of JLM Visuals.)*

Words to Know

Acidification: An increase over time in the content of acidity in a system, accompanied by a decrease in the acid-neutralizing capacity of that system.

Acidifying substance: Any substance that causes acidification, either directly or indirectly, as a result of chemical changes.

Acidity: The quality, state, or degree of being acidic. Acidity is usually measured as the concentration of hydrogen ions in a solution using the pH scale. A greater concentration of hydrogen ions means a more acidic solution and a lower corresponding pH number. Strictly speaking, an acidic solution has a pH less than 7.0.

Leaching: The movement of dissolved chemicals with water that is percolating, or oozing, downward through the soil.

Neutralization: A chemical reaction in which the mixing of an acidic solution with a basic (alkaline) solution results in a solution that has the properties of neither an acid nor a base.

Oxide: A compound containing oxygen and one other element.

pH: A measure of acidity or alkalinity of a solution referring to the concentration of hydrogen ions present in a liter of a given fluid. The pH scale ranges from 0 (greatest concentration of hydrogen ions and therefore most acidic) to 14 (least concentration of hydrogen ions and therefore most alkaline), with 7 representing a neutral solution, such as pure water.

destruction of some plant and animal populations. It is not yet certain that land-based ecosystems have been affected by acidic deposition.

After acid rain was discovered in Europe, scientists began measuring the acidity of rain in North America. Initially, they found that the problem was concentrated in the northeastern states of New York and Pennsylvania because the type of coal burned there was more sulfuric. Yet by 1980, most of the states east of the Mississippi, as well as areas in southeastern Canada, were also receiving acidic rainfall. Acid rain falls in the West as well, although the problem is not as severe. Acid rain in Los Angeles, California, is caused primarily by automobile emissions.

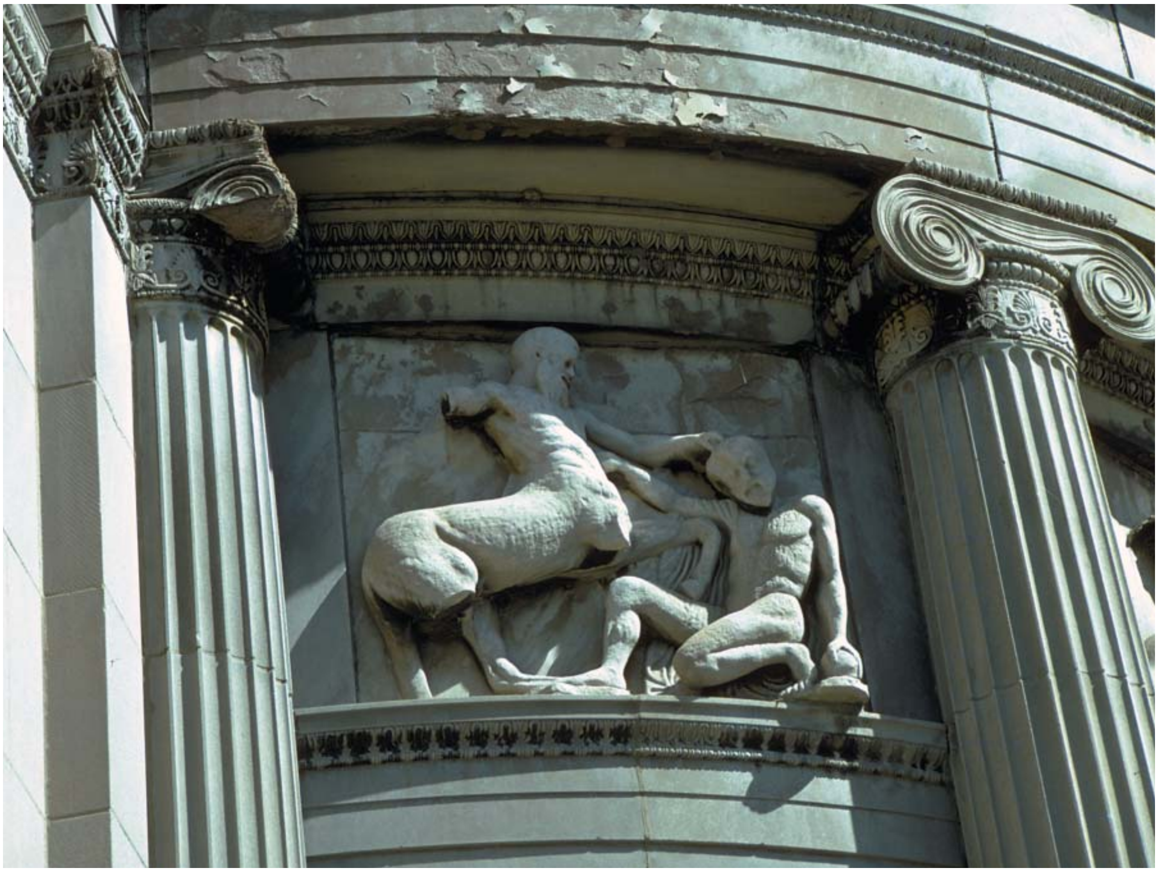
How is acid rain measured?

Acid rain is measured through pH tests that determine the concentration of hydrogen ions in a liter of fluid. The pH (potential for hydrogen) scale is used to measure acidity or alkalinity. It runs from 0 to 14. Water has a neutral pH of 7. (The greater the concentration of hydrogen ions and the lower the pH number, the more acidic a substance is; the lower the concentration of hydrogen ions and the higher the pH number, the more alkaline—or basic—a substance is.) So a pH greater than 7 indicates an alkaline substance while a pH less than 7 indicates an acidic substance.

It is important to note that a change of only one unit in pH equals a tenfold change in the concentration of hydrogen ions. For example, a solution of pH 3 is 10 times more acidic than a solution of pH 4.

Normal rain and snow measure about pH 5.60. In environmental science, the definition of acid precipitation refers to a pH less than 5.65.

Acid rain can erode structures such as buildings, even if they are made out of stone. *(Reproduced by permission of JLM Visuals.)*



Measured values of acid rain vary according to geographical area. Eastern Europe and parts of Scandinavia have rain with pH 4.3 to 4.5; rain in the rest of Europe is ranges from pH 4.5 to 5.1; rain in the eastern United States and Canada ranges from pH 4.2 to 4.6, and the Mississippi Valley has a range of pH 4.6 to 4.8. The worst North American area, analyzed at pH 4.2, is centered around Lake Erie and Lake Ontario.

When pH levels are drastically upset in soil and water, entire lakes and forests are endangered. Evergreen trees in high elevations are especially vulnerable. Although the acid rain itself does not kill the trees, it makes them more susceptible to disease. Also, high acid levels in soil causes leaching (loss) of other valuable minerals such as calcium, magnesium, and potassium.

Small marine organisms cannot survive in acidic lakes and rivers, and their depletion (reduced numbers) affects the larger fish who usually feed on them, and, ultimately, the entire marine-life food chain. Snow from acid rain is also damaging; snowmelt has been known to cause massive, instant death for many kinds of fish. Some lakes in Scandinavia and New York's Adirondack Mountains are completely devoid of fish life. Acid rain also eats away at buildings and metal structures. From the Acropolis in Greece to Renaissance buildings in Italy, ancient structures are showing signs of corrosion from acid rain. In some industrialized parts of Poland, trains cannot exceed 40 miles (65 kilometers) per hour because the iron railway tracks have been weakened from acidic air pollution.

Treatment of water bodies affected by acid rain

Usually, waters affected by acid rain are treated by adding limestone or lime, an alkaline substance (base) that reduces acidity. Fishery biologists especially are interested in liming acidic lakes to make them more habitable (capable of being lived in) for sport fish. In some parts of Scandinavia, for instance, liming is used extensively to make the biological damage of acidification less severe.

Avoiding acid rain

Neutralizing (returning closer to pH 7) ecosystems that have become acidic treats the symptoms, but not the sources, of acidification. Although exact sources of acid rain are difficult to pinpoint and the actual amount of damage caused by acid deposition is uncertain, it is agreed that acid

rain levels need to be reduced. Scientific evidence supports the notion that what goes up must come down, and because of public awareness and concerns about acid rain in many countries, politicians have begun to act decisively in controlling or eliminating human causes of such pollution. Emissions of sulfur dioxide and nitrogen oxides are being reduced, especially in western Europe and North America. For example, in 1992 the governments of the United States and Canada signed an air-quality agreement aimed at reducing acidifying depositions in both countries.

While countries in western Europe and North American have actively carried out actions to reduce emissions of gases leading to acid deposition for a number of years, countries in other parts of the world have only recently addressed the issue. In eastern Europe, Russia, China, India, southeast Asia, Mexico, and various developing nations, acid rain and other pollution problems are finally gaining notice. For example, in 1999, scientists identified a haze of air pollution that hovers over the Indian Ocean near Asia during the winter. The 3.8 million-square-mile haze (about the size of the combined area of all fifty American states) is made up of small by-products from the burning of fossil fuels. Such a cloud has the potential to cool Earth, harming both marine and terrestrial life.

[*See also* **Acids and bases; Forests; Pollution**]

Acids and bases

Acids and bases are chemical compounds that have distinctive properties in water solution. The sour taste of a lemon, lime, or grapefruit, for example, is caused by citric acid. The slippery feel of ammonia, a common base, is characteristic of all bases. One of the most interesting properties of acids and bases is the way they react with indicators. An indicator is a material that changes color in the presence of an acid or a base. For instance, the hydrangea flower can be either pink or blue, depending on the amount of acid or base present in the soil in which it is planted.

Acids and bases have been known since prehistoric times. Vinegar, for example, is a water solution of acetic acid that has been used for centuries. The first modern definitions for acids and bases were suggested by Swedish chemist Svante Arrhenius (1859–1927). Arrhenius proposed that acids be defined as chemicals that produce positively charged hydrogen ions, H^+, in water. By comparison, he suggested that bases are compounds that produce negatively charged hydroxide ions, OH^-, in water. Acids and bases react with each other in a reaction called neutralization. In a neu-

tralization reaction, the hydrogen ion from an acid and the hydroxide ion from a base react to form a molecule of water:

$$H^+ + OH^- \rightarrow H_2O$$

Other definitions of acids and bases

Since the time of Arrhenius, chemists have adopted other ways of defining acids and bases. In 1923, English chemist Thomas Lowry (1874–1936) and Danish chemists J. N. Brønsted (1879–1947) and N. Bjerrum (1879–1958) suggested defining acids as chemicals that donate a proton (specifically H^+) in a chemical reaction and bases as chemicals that accept a proton. This definition is slightly more comprehensive than Arrhenius's definition and, in many cases, more useful to chemists.

Another definition of acids and bases was suggested in 1923 by American chemist Gilbert Newton Lewis (1875–1946). According to Lewis, an acid could be thought of as any compound that accepts a pair of electrons from another substance; bases, on the other hand, could be thought of as compounds that donate a pair of electrons.

Most acids and bases fit all three of these definitions, but some are covered by only one or both of the more modern definitions.

Strong and weak acids and bases

One of the most important characteristics of acids and bases is their strength. The strength of an acid or base depends on the number of hydrogen ions or hydroxide ions produced in water solution. For example, suppose that 100 molecules of an acid are added to water. Of those 100 molecules, imagine that 99 release hydrogen ions. That acid is said to be a strong acid. In comparison, suppose that 100 molecules of a second acid release only 10 hydrogen ions in water. That acid is said to be a weak acid.

Examples of strong acids are hydrochloric acid (HCl), sulfuric acid (H_2SO_4), and nitric acid (HNO_3). Among the best-known strong bases are sodium hydroxide (NaOH), potassium hydroxide (KOH), and calcium hydroxide ($CaOH_2$). The weak acids include acetic acid ($HC_2H_3O_2$), lactic acid ($CH_3CHOHCOOH$), and oxalic acid ($H_2C_2O_4$). The most familiar weak base is ammonia (NH_3).

Neutralization

Acids and bases are sometimes described as the chemical opposites of each other. If equivalent quantities of an acid and a base are combined, the two compounds react to form a salt and water. For example:

$$HCl + NaOH \rightarrow NaCl + H_2O$$
$$\text{hydrochloric acid} + \text{sodium hydroxide} \rightarrow \text{sodium chloride} + \text{water}$$

This process is known as neutralization.

Neutralization has many practical applications. For example, agricultural land is often too acidic or too basic to grow certain crops. Farmers can add either a weak acid or a weak base to produce the level of acidity or basicity in which various plants grow best. Reclamation (restoration) of land once used for mining also involves neutralization reactions. Such land is often too acidic for plants to grow. Treating the land with calcium oxide neutralizes acids remaining in the soil and restores its fertility.

Neutralization is also used to deal with environmental problems. Gases produced in factories, power generating plants, and other industrial facilities are usually acidic. When they escape into the air, they react with water to form acid rain. Scrubbers that contain bases can be attached to the inside of smokestacks in such plants to neutralize acids in escaping gases. Treatment with acids or bases is also used to neutralize hazardous chemicals produced by a variety of manufacturing operations.

Uses of acids and bases

Acids and bases can be found everywhere in the world around us. Lactic acid occurs in sour milk, citric acid in citrus fruits, oxalic acid in rhubarb, malic acid in apples, and tartaric acid in wine. Baking soda, antacids, and lye all contain bases.

Acids and bases are also used widely in industry. Three of the top ten chemicals produced in the United States each year are acids or bases. In 1994, 40 billion kilograms (or about 90 billion pounds) of sulfuric acid were manufactured in the United States, making it the number one chemical in the chemical industry. In addition, 12 billion kilograms (about 26 billion pounds) of sodium hydroxide and 11 billion kilograms (about 25 billion pounds) of phosphoric acid were produced.

The most important single use of acids and bases is in the manufacture of other chemicals. Fertilizers, synthetic fabrics, pigments, petroleum, iron and steel, explosives, dyes, plastics, pesticides, soaps and detergents, paper, film, and many other chemicals are produced from acids and bases. They are also used for various other purposes, including cleaning surfaces, refining oil and sugar, electroplating metals, and treating food products.

Acoustics

Acoustics is the science that deals with the production, transmission, and reception of sound. The first scientist to study sound scientifically was German physicist Ernst Florens Friedrich Chladni (1756–1827). Chladni was an amateur musician who became interested in finding mathematical equations to describe musical sounds. Because of his work, he is often called the father of acoustics.

Acoustics has many applications in the everyday world. When you have your hearing checked by a technician, that person makes use of the principles of acoustics. Those same principles are also used in the architectural design of concert halls.

The study of sound can be subdivided into three parts: production, transmission, and reception. All three elements are necessary in order for sound to occur. For example, a ringing alarm clock cannot be heard if it

A scientist at Bell Telephone Laboratories in 1965 listening to music in a specially designed room that does not produce echoes or reverberations. *(Reproduced by permission of AT&T Bell Laboratories.)*

Words to Know

Amplitude: The maximum displacement (difference between an original position and a later position) of the material that is vibrating. Amplitude can be thought of visually as the highest and lowest points of a wave.

Condensations: Regions of high density in a sound wave traveling through a gas such as air.

Cycle: A single complete vibration.

Cycles per second: The number of complete vibrations per second.

Frequency: The rate at which vibrations take place (number of times per second the motion is repeated), given in cycles per second or in hertz (Hz).

Fundamental: The lowest frequency of vibration of a sound-producing body (also called the first harmonic).

Harmonics (first, second, etc.): The various frequencies of vibration of a sound-producing body, numbered from the one of lowest frequency to higher frequencies.

Hertz (Hz): The unit of frequency; a measure of the number of waves that pass a given point per second of time.

Infrasonic vibrations: A rate of vibration below the range of human hearing, that is, below about 10 cycles per second.

Longitudinal wave: A wave whose motion of vibration is in the direction of the wave's advancement—the same direction in which the wave is traveling.

Loudspeaker: A device to produce sounds from an electric current—by electrical and mechanical means—in the range of frequencies around the sonic range (that is produced by humans).

is placed inside a jar from which all air has been removed. Without air, sound produced by the clock has no medium through which it can travel.

Production of sound in a string

Sound is produced by a vibrating body. The vibrating body can be a string on a violin or piano, a column of air in an organ pipe or clarinet, an animal skin or piece of plastic stretched over a drum, or the vocal cords in a person's throat, to name but a few. A simple way to illustrate the

Medium: A material that carries the acoustic vibrations away from the body producing them.

Microphone: A device to change sounds—by electrical and mechanical means—into an electric current having the same frequencies as the sound, in the range of frequencies around the sonic range (that is produced by humans).

Node: A place where the amplitude of vibration is zero.

Overtones: The set of harmonics, beyond the first, of a sound-producing body.

Rarefactions: Regions of low density in a sound wave traveling through a gas such as air.

Sonar: A device utilizing sound to determine the range and direction of an underwater object.

Transverse wave: A wave traveling in a direction perpendicular to (at right angles to, or like an upside-down T) the motion of the vibrating body.

Ultrasonic vibrations: Vibrations greater than those that can be detected by the human ear (above about 20,000 cycles per second).

Wave: A motion in which energy and momentum is carried away from some source; a wave repeats itself in space and time with little or no change.

Wavelength: The distance, at any instant of time, between parts of a vibrating body having the identical motion.

production of sound is by studying the vibration of a string, as shown in the acoustics diagram (shown on page 20).

Imagine that the string in this diagram is stretched tightly and then plucked. The way in which the string vibrates depends on a number of factors, including the material from which the string is made, the object with which it is plucked, and the force exerted when plucking on the string. The simplest type of vibration, shown in Figure 1, is called the fundamental or first harmonic.

Real strings do not vibrate with the simple pattern shown in Figure 1. Instead, they vibrate in a complex pattern that consists of vibrations within vibrations. Figure 2 illustrates another kind of vibration in the string called the second harmonic. Notice that the vibration occurs in two sections of the string separated by a point where no vibration occurs. That point is called a node.

Other vibrations may occur at the same time. Figure 3 shows the third harmonic in the string. Harmonics above the first are also known as overtones. This diagram shows the first harmonic and two overtones.

As with all forms of wave motion, a vibrating string can be described completely with only a few variables. The rate at which the string vibrates up and down is known as its frequency. Frequency is usually measured in cycles (vibrations) per second. The unit used to measure frequency is the hertz (abbreviation: Hz). A string might be vibrating, for example, at 1,000 Hz, or 1,000 cycles per second.

The distance between two identical parts of a wave is called the wavelength. Notice that the upward motion of the wave starts at the far left of the string in Figure 2 and is not repeated until the far right of the string. The letter L in the figure shows the wavelength of this wave. The highest point reached by a wave above its average height is the amplitude. The amplitude in the figures is represented by the letter A.

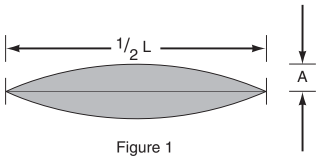


Figure 1

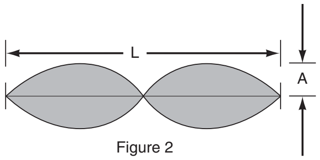


Figure 2

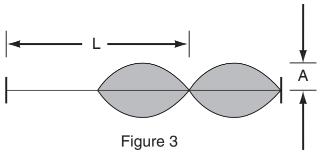


Figure 3

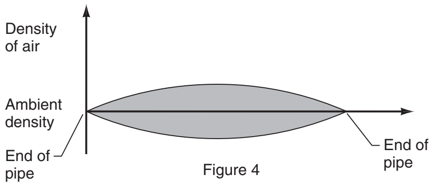


Figure 4

When a musician plays a stringed instrument, he or she can control the way in which the string vibrates by varying the points at which the string is held and the way in which the string is bowed or plucked.

Other ways of producing sound

Sound produced in a vibrating column of air can be analyzed in much the same way as sound produced by a vibrating string. Look at Figure 4 and imagine that a musician has blown into the column of air from the left, as shown by the arrow. Air within the column is pushed from left to right, producing waves similar to those in the vibrating string. The main difference is that the waves of air are longitudinal waves (meaning they travel in the direction of the column) while the waves in the string are transverse waves (meaning they travel at right angles to the string).

The waves in the air column consist of two distinct types: regions where air piles up and becomes more dense, and regions where air spreads out and becomes less dense. More dense regions of air are known as condensations and less dense regions as rarefactions. The pattern of condensation and rarefaction differ depending on whether the column in which they occur is open or closed at one or both ends. As with a stringed instrument, overtones produced by an oboe, clarinet, bassoon, or other wind instrument are determined by the points at which the air column is blocked off and by the force with which air is pushed through the column.

One of the most complex wind instruments is the human voice. Sound is produced by humans when they force air across the vocal cords, causing them to vibrate. The various overtones produced by this process are determined by a number of factors, including the size and shape of various cavities in the head (such as the sinuses), as well as the placement of the tongue and the shape of the mouth. With so many factors involved, it is hardly surprising that each human voice has a distinctive sound.

Detectable and undetectable sounds

Objects can be made to vibrate with a great range of frequencies, from only a few cycles (or vibrations) per second to millions of times per second. However, the human ear is able to detect only a limited range of those vibrations, generally those between 20 to 18,000 Hz. When the rate of vibration is less than 20 Hz, the sound is said to be infrasonic; when the rate is above 18,000 Hz, it is said to be ultrasonic. Although ultrasonic vibrations cannot be heard, they do have a number of research and industrial applications.

Transmission of sound

Since light and sound both consist of waves, they are transmitted in similar ways. The most important difference between the two is their wavelengths. Visible light has wavelengths between about 400 and 700 nanometers (billionths of a meter), while sound has wavelengths between about 3.3 centimeters and 3.3 meters. This difference shows up in the way light and sound are affected by objects placed in their paths.

In general, a wave is blocked by any object in its path if the object is has dimensions greater than its wavelength. In the case of light, then, any object larger than 700 nanometers will block the path of light. You know this from everyday life. If you place a book in front of a beam of light, you can no longer see the light. The book casts a shadow because it is much larger than the wavelength of light.

But placing a book in the path of a sound wave does not block out the sound. The size of the book (less than a meter) is much less than the wavelength of the sound wave. The sound wave acts as if the book is not even there.

This principle has some important practical applications. Many communities are building walls to block off the sound of nearby freeway traffic. In order for this type of construction to work, the wall must have dimensions that are larger than the sound waves coming from the freeway, that is, dimensions greater than 3.3 meters. When a wall is large enough, it casts an acoustical shadow, similar to the light shadow cast by a book.

Reception of sound

By far the most important sound receiver in use is the human ear. Although the details of the workings of the ear are complicated, the general principles by which humans hear are fairly simple. When sound waves reach the outer ear, they pass down the ear canal and strike the eardrum. The eardrum consists of a thin membrane that vibrates with the same frequency as the sound wave. The vibrating membrane of the eardrum, in turn, causes three small bones in the middle ear—the malleus, incus, and stapes—to vibrate, too. (These three bones are more commonly called the hammer, anvil, and stirrup because of their shapes.)

The last of the three bones, the stapes, is connected to a fluid-filled chamber called the cochlea. Vibrations from the stapes are passed to the cochleal fluid and then on to tiny hairs that line the cochlea. These hairs change the wave motion of sound into an electrical signal that is transmitted along the auditory (hearing) nerve to the brain. Finally, the brain interprets the meaning of the sound/electrical wave, allowing a person to perceive the sound.

Applications

The many applications of acoustical devices are easy to find in the world around you: telephones, radios and television sets, compact disc players and tape recorders, and even clocks that "speak" the time are common examples. One of the most important acoustical devices from the human point of view is the hearing aid. The hearing aid is a system consisting of miniature microphones, amplifiers, and loudspeakers that make it easier for people with hearing difficulties to understand sounds.

One of the first large-scale industrial applications of acoustics was sonar. Sonar stands for the phrase *so*und *na*vigation *r*anging. It was developed by the U.S. military during World War I (1914–18) for the detec-

tion of submarines and continues to be an invaluable device for navies throughout the world. The sonar system is based on readings of sent and received sound waves. A ship looking for underwater objects (such as a submarine) sends out a sound signal. If that sound signal strikes an object, such as the hull of a submarine, it is reflected back to the detecting ship in an echo. The nature of the echo tells an observer the direction and distance of the object (in this case, the submarine hull) that was hit by the wave.

Listening devices can also be used to study sounds emitted by an underwater object. Each type of submarine and each type of engine emit distinctive sound patterns that can be picked up and analyzed by listening devices on other ships.

Sonar has uses other than in military applications. For example, fishing fleets can use sonar to locate schools of fish, determine their size, and track their movement.

Acoustical principles are now used widely in the construction of concert halls and auditoriums. For many years, scientists have known that music and the spoken word can be more clearly and easily heard in certain types of rooms. Only recently, however, have the scientific principles of acoustics been understood well enough to apply them to the actual construction of halls and auditoriums.

The field of ultrasonics has become an important subspecialty in the science of acoustics. Ultrasonic sources with frequencies of millions of cycles per second are now used for inspecting metals for flaws. These waves reflect off tiny imperfections in a metal, indicating where it is weak or likely to fail. Some of the structures that are now routinely inspected by ultrasonic techniques are bridges, airplanes, and pipelines.

Actinides

The actinides (or actinoids) are the chemical elements with atomic numbers between 90 and 109 inclusively. (An atomic number indicates the number of protons in an atom.) Actinides occur between Groups 3 and 4 in Period 7 of the periodic table. All elements in this family are radioactive (that is, they spontaneously release subatomic particles or energy as their nuclei decay). Five actinides have been found in nature: thorium, protoactinium, uranium, neptunium, and plutonium. The other actinides have been produced artificially in nuclear reactors or particle accelerators (atom-smashers).

History

For many years, the list of chemical elements known to scientists ended with number 92, uranium. Scientists were uncertain as to whether elements heavier than uranium would ever be found. Then, in 1940, a remarkable discovery was made while University of California physicists Edwin McMillan (1907–1991) and Philip Abelson (1913–) were studying nuclear fission. (Nuclear fission is the splitting of an atomic nucleus, a process that releases large amounts of energy. Atomic bombs and nuclear power plants operate on nuclear fission.) During their research, the duo found evidence for the existence of a new element with atomic number 94, two greater than that of uranium.

This new element was the first transuranium (heaver than uranium) element ever discovered. McMillan and Abelson named it neptunium, after the planet Neptune, just as uranium had been named after the planet Uranus. Later in the same year, McMillan and two other colleagues found a second transuranium element, which they named plutonium, after the planet Pluto.

At that point, the race was on to develop more synthetic transuranium elements, but the research process was not easy. The approach was to fire subatomic particles or small atoms, like those of helium, at a very large nucleus by means of a particle accelerator. If the smaller particle could be made to merge with the larger nucleus, a new atom would be produced. Over time, techniques became more and more sophisticated, and ever-heavier elements were created: americium (number 95) and curium (number 96) in 1944; berkelium (number 97) in 1949; californium (number 98) in 1950; einsteinium (number 99) and fermium (number 100) in 1952; mendelevium (number 101) in 1955; nobelium (number 102) in 1958; and lawrencium (number 103) in 1961.

Studies of the actinide elements are among the most ingenious in all of chemistry. In some cases, no more than one or two atoms of a new element have been produced. Yet scientists have been able to study those few atoms well enough to discover basic properties of the elements. These studies are made even more difficult because most actinide isotopes (atoms of a chemical element that are similar but not exactly alike) decay quickly, with half-lives of only a

few days or a few minutes. (A half-life is the amount of time required for half of the atoms of a radioactive substance to disintegrate.)

With the discovery of lawrencium, the actinide family of elements is complete. Scientists have also found elements heavier than lawrencium, but these elements belong to the lanthanide family (or rare earth elements).

Uranium

Uranium is a dull gray metallic element with a melting point of 1,135°C (2,075°F) and a boiling point of 4,134°C (7,473°F). It is relatively abundant in Earth's crust, ranking number 47 among the elements. Although perhaps not as well known, it is actually more abundant than more familiar elements such as tin, silver, mercury, and gold. Natural uranium consists of three isotopes of mass numbers 234 (0.005 percent), 235 (0.711 percent), and 238 (99.283 percent). All three isotopes are radioactive.

Properties and uses. By far the most important property of uranium is its radioactivity. Its most abundant isotope, uranium-238, decays by emitting an alpha particle with a half-life of 4.47×10^9 years. (Recall that the half-life of a radioactive element is the time it takes for one-half of a given sample to decay.) The half-life of uranium-238 is about equal to the age of Earth. That means that about one-half of all the uranium found on Earth at its moment of creation is still here. The other one-half has decayed to other elements.

Knowing the half life of uranium-238 (and many other radioactive isotopes) allows scientists to estimate the age of rocks. The amount of uranium-238 found in any particular rock is compared to the amount of daughter isotopes found with it. A daughter isotope is an isotope formed when some parent isotope, such as uranium-238, decays. The more daughter isotope present in a sample, the older the rock; the less daughter isotope, the younger the rock.

The second most abundant isotope of uranium, uranium-235, has the rare property of being fissionable, meaning that its atomic nuclei will break apart when bombarded by neutrons. The fission of a uranium-235 nucleus releases very large amounts of energy, additional neutrons, and two large fission products. The fission products are the atomic nuclei formed when a fissionable nucleus such as uranium-235 breaks apart.

The fission of uranium-235 nuclei has become extremely important in the manufacture of nuclear weapons and in the operation of nuclear power plants. In fact, these applications account for the primary applications of uranium in everyday life.

Thorium

Thorium is a soft metal with a bright silvery luster when freshly cut. It has a melting point of about 1,700°C (3,100°F) and a boiling point of about 4,500°C (8,100°F). It is relatively soft, with a hardness about equal to that of lead. It is even more abundant than uranium, ranking number 39 in abundance among the elements in Earth's crust.

No more than a few hundred tons of thorium are produced annually. About one-half of this production goes to the manufacture of gas mantles, insulated chambers in which fuel is burned. The rest goes for use as nuclear fuel, in sunlamps (electric lamps that emit radiation; often used for tanning), in photoelectric cells (vacuum tubes in which electric current flows when light strikes the photosensitive—or light sensitive—cathode), and in the production of other alloys (a mixture of two or more metals or a metal and a nonmetal).

Uses of other actinides

At one time, the actinides other than uranium were no more than scientific curiosities. They were fascinating topics of research for scientists but of little practical interest. That situation has now changed, and all of the actinides that can be prepared in large enough quantities have found some use or another. Plutonium, for example, is used in the manufacture of nuclear weapons and as the power source in nuclear power plants. On a smaller scale, it is also used as a power source in smaller devices such as the heart pacemaker. Californium is used in smoke detectors, curium is a power source in space vehicles, and americium is utilized in the treatment of cancer.

[*See also* **Element, chemical; Isotope; Nuclear fission; Periodic table; Radioactivity**]

Adaptation

Adaptation is a term used to describe the ways in which organisms change over time in response to the changing demands of their environment. Organisms seem to accumulate certain physiological, behavioral, and structural traits gradually, and these traits aid them in their ability to survive and reproduce under existing environmental conditions. The grasping hands of primates, the sensitive antennae of insects, and the flowers and fruits of plants are all forms of adaptation that promote survival, reproduction, or both.

Words to Know

Adaptation: From the Latin ad ("toward") plus aptus ("fit for some role"); any structural, physiological, or behavioral trait that aids an organism's survival and ability to reproduce in its existing environment.

Coadaptation: Mutual dependence between members of two species.

Evolution: The theory that all plants and animals developed gradually from earlier forms over a long period of time and that variations within a species are the result of adaptive traits passed on from generation to generation.

Exaptation: Any adapted trait that performs a beneficial function different from the one it originally evolved to serve.

Natural selection: A natural process that results in the survival of individuals or groups best adapted to the conditions in which they must exist.

Historical background

Up until the eighteenth century, scientists generally believed that every species was created separately and remained unchanged for centuries. Many features of living things—the bee's sting, the vertebrate (an animal with a backbone) eye, the human brain—appeared to have been designed by a master engineer to serve their specific purpose. A philosophy known as natural theology, which arose in the seventeenth century, argued that the elegant and often complex features of organisms were the products of a direct design by God.

But during the eighteenth century, the scientific community began to take a closer look at the immense diversity (the vast differences) and interrelatedness of (connections between) living things. The excavation of plant and animal fossils prompted a new view that life on Earth developed gradually and unevenly from simple to advanced organisms. The observation that species have "adapted" to survive in particular habitats raised new questions about the ways organisms could "fine-tune" themselves to meet the demands of their environment.

Different species that live in different environments often exhibit similar characteristics. Fish, whales, and penguins all use fins or flippers

The Peppered Moth

Henry Bernard David Kettlewell's study of the peppered moth, *Biston betularia*, is one of the most widely cited cases of natural selection producing adaptation. Before the Industrial Revolution in England in the late 1800s, this moth was predominantly light in color. (The Industrial Revolution was a time of major change in England's economy, marked mainly by the introduction of power-driven machinery.) Light coloring afforded perfect camouflage for the moth from predatory birds, since it blended so well with the similarly colored lichen-covered tree trunks on which it rested. When pollution from factories caused the lichen on the trees to die, the moths' resting place became the darker color of the bark beneath. Kettlewell observed that, as this environmental transformation occurred, a dark form of the moth became increasingly common, eventually making up more than 90 percent of the population of moths in the affected areas. In the unpolluted areas, however, the original light form of the moth remained common.

Kettlewell attributed the moth's color change to selection by predatory birds, which locate the moths by sight, and so remove (by eating) individual moths that do not blend in with the background coloration of trees in their environment. He tested his idea that the moths' color protected them from predation (being captured) by placing each of the two forms on trees in different areas, photographing birds in the act of capturing moths, and measuring the rates at which the two moth forms were eaten by birds. Kettlewell concluded that the moths' color was indeed the result of adaptation to conditions in their habitat.

to propel themselves through water. The common plan of such features demanded an explanation, so researchers set out to explain this similarity of traits in unrelated organisms.

One effort to explain adapted traits was proposed by French botanist Jean-Baptiste Lamarck (1744–1829). In 1809, he theorized that changes in the environment cause structural changes during an organism's life that are passed on to offspring. According to the notion of the inheritance of acquired characteristics, also known as Lamarckism, giraffes would have "acquired" their long necks from stretching to reach leaves not available to other animals. Members of each succeeding generation stretched their necks to attain leaves at a higher level, which led to the modern giraffe.

Although Lamarck's theory was later discredited, he remains the first scientist to acknowledge the adaptability of organisms.

In 1859, Charles Darwin (1809–1882), the great English naturalist, published his influential book *The Origin of Species by Means of Natural Selection.* In it, Darwin discusses the adaptations of organisms as the product of natural selection. Natural selection implies that—when forced to compete for limited resources such as food—those organisms best adapted to their specific environment are most likely to survive, reproduce, and transmit their traits to offspring.

A boojum tree in Mexico during the dry season. The plant has adapted to seasonal changes in precipitation by restricting leaf growth in the dry season. *(Reproduced by permission of JLM Visuals.)*

Biologists now recognize natural selection as the means by which evolutionary adaptation occurs. Exactly how specific adaptations arise, however, is far from solved. It is easy to imagine how natural selection might produce relatively simple adaptations such as camouflage: a rabbit that lives in regions covered by snow in winter is better protected from prey if it produces a white coat during the winter months. The difficulty arises in explaining the evolution of extremely complex adaptations, such as the vertebrate eye. Invertebrates, animals lacking a backbone, have simple eyes that detect only changes in light and form only a poor image at

A boojum tree in Mexico during the moist season. The plant has adapted to seasonal changes in precipitation by maintaining leaves only in the moist season. *(Reproduced by permission of JLM Visuals.)*

best. Vertebrates, animals with a backbone, detect changes in light and motion and can form detailed images. How did such a superb adaptation come about?

Darwin suggested the answer lies in very gradual changes over many generations, in which each intermediate stage leading to a fully formed eye had some adaptive value. All the parts making up a fully functioning eye could evolve independently in small steps, each one building on and interacting with earlier changes. Thus, even a partially developed eye could be quite advantageous—indeed, could mean the difference between life and death—for an ancient vertebrate.

Examples of adaptation

Physiological adaptation. People who visit or live at high altitudes undergo physiological changes (adaptations) to adjust to the low-oxygen environment. Travelers to these areas commonly experience hypoxia, a condition of low oxygen in the blood. To compensate for the temporary drop in oxygen, vacationers' bodies speed up the oxygenation process: they breathe at a faster rate, their hearts speed up and pump more strongly to send more blood throughout the body, and they produce more red blood cells to carry oxygen to body tissues. Over a longer period, as the body adjusts to the change in altitude, the heart output and ventilation rate return to normal levels, but the red blood cell count continues to climb. The most famous of all high-altitude peoples are the Sherpas of Nepal, whose climbing feats offer a stunning example of evolved adaptation.

Evolutionary adaptation. Some of the most interesting cases of adaptation occur when two species evolve together so that each benefits from the other. This mutual dependence can be seen between the ant *Formica fusca* and the larval (not yet fully developed) stage of the lycaenid butterfly *Glaucopsyche lygdamus.* The butterfly caterpillar produces a sweet "honeydew" solution that the ants harvest as food. In return, the ants defend the caterpillar against parasitic wasps and flies. The mutual adaptation of two species in this manner is known as coadaptation.

Interactions between species are not always beneficial for both members, however. *Heliconius* butterflies scatter the pollen from the flowers of *Passiflora* vines, benefitting the plant. But female butterflies also lay single eggs on young *Passiflora* shoots, and the developing larva may eat the entire shoot, a definite cost to the plant. As an apparent adaptive response, several *Passiflora* species produce new shoots featuring a small structure that closely resembles a *Heliconius* egg. A female butterfly that sees this "egg" will avoid laying her own egg there, and the shoot will be spared.

Current approaches to adaptation

Some researchers draw a distinction between current use and the historical origin of adaptive traits. This distinction has led researchers Stephen Jay Gould and Elisabeth Vrba to suggest the term exaptation to describe traits that were originally intended to perform different functions in an organism. For instance, the observation that a white coat helps camouflage a snowshoe hare in the snow does not provide information about the origin of the species' white fur. It may have evolved for its improved heating properties and only by chance proved to be advantageous as camouflage. In some cases, therefore, the features we recognize as adaptive are really only secondary uses of traits that originally arose for other reasons.

[*See also* **Evolution**]

Addiction

Addictions can be physical (of the body), psychological (of the mind), or both. In fact, almost any behavior can be termed an addiction if it becomes the primary focus of a person's life, and especially if it results in harmful effects to one's physical health and well-being. The term addiction is most commonly associated with a person's compulsive and habitual desire to consume a chemical substance, such as alcohol or other drugs. The addict's life is eventually dominated by the craving. It is estimated that up to 25 percent of the American population displays some form of addictive behavior.

Chemical addictions

Alcohol. Alcohol is a central nervous system depressant that reduces inhibitions and anxiety. As the body becomes accustomed to a particular quantity of alcohol, more and more alcohol is needed to alter the drinker's mental state in the desired way. Eventually, the liver (an organ that plays a key role in digestion, filtration of the blood, and the storage of nutrients) can become damaged by constant exposure to alcohol and its metabolites (by-products of alcohol's breakdown). A damaged liver loses its ability to detoxify the blood, which can result in permanent mental changes, organ failure, and death.

The opiates: opium, morphine, and heroin. Opiates (also called narcotics) are addictive drugs derived from opium, a drug made from poppy juice. They have a narcotic effect upon the body, meaning they dull the

Words to Know

Detoxify: To remove poisonous substances from the body, generally performed by the liver and kidneys.

Endorphins: A group of naturally occurring substances in the brain that act as analgesics, or pain relievers, and are released in response to emotional or physical stress; sometimes referred to as "internal morphine."

Narcotic: A drug, such as an opiate, that dulls the senses, relieves pain, and causes sleep.

Opiate: Any derivative of opium, for example, morphine or heroin.

Withdrawal: The act of giving up the use of a drug by an addict, usually accompanied by unpleasant symptoms.

senses. In moderate doses, they relieve pain, promote a sense of well-being, and induce sleep; excessive doses, however, can cause coma or convulsions. Opiates include opium and its derivatives—morphine and heroin.

Opium, a drug derived from the poppy, has been known since ancient times for its pain-relieving qualities and its ability to induce sleep. From the 1600s through the 1800s, it was widely used in Western medicine to treat a variety of ailments and was highly effective in deadening the sensation of pain during surgery. In China, addictive opium smoking was rampant by the late 1700s, where opium dens flourished. Some artists and writers of the nineteenth century claimed that opium use intensified their creativity by reducing their inhibitions.

Opium is grown around the world, and in some countries smoking the drug continues to be common, though it is outlawed except for medicinal purposes in most Western nations. Preparations of opium, such as paregoric, are sometimes prescribed for diarrhea. Codeine, an opium derivative, is an ingredient in many pain-relieving medications and cough syrups.

Morphine is the active ingredient in opium. Discovered in 1805 by Friedrich Sertürner (1783–1841), a German pharmacist, it is the most effective naturally occurring compound used for the relief of pain in medicine and surgery. Its narcotic properties also produce a calming effect, protecting the body's system during traumatic shock. Once the hypodermic syringe (needle) was invented in 1853, the use of morphine injec-

tions for the relief of pain was adopted enthusiastically by the medical community. (Some doctors even taught their patients how inject themselves.) Morphine's popularity extended to America's Civil War battlefields, where the drug was used to treat wounded soldiers. Tragically, thousands of people worldwide became addicted to the drug.

In 1898, the Bayer corporation (the maker of aspirin) synthesized (produced by chemical means) heroin from morphine and marketed it as a remedy for morphine addiction. Heroin, however, proved to be even more addictive than morphine. Used in a powder form that is dissolved in water and injected into the user's vein, heroin provides an immediate sensation of warmth and relaxation. Physical or mental pain is relieved, and the user enters a deeply relaxed state for a few hours. The powder also can be inhaled for a milder effect. Heroin is extremely habit-forming: with only a few doses the user is "hooked."

Cocaine. Cocaine is a white, crystalline powder produced from the leaves of the coca plant, a South American shrub. It is extremely and powerfully addictive—some people need only a single exposure for addiction to occur. For centuries, South American Indians have chewed the coca leaves for their stimulating and exhilarating effect. Cocaine came into use as a local anesthetic in the late 1800s because of its numbing properties. As a pain reliever and stimulant, it was a common ingredient in popular nonprescription medicines of the late 1800s and early 1900s. By the end of the twentieth century, cocaine was used only occasionally in the medical field, sometimes as a local anesthetic for some kinds of surgery. Most cocaine now is purchased and used illegally. The white powder is often inhaled ("snorted"), sometimes injected, and as free base is smoked. A solid crystalline form known as crack, the most potent form of cocaine, is also smoked. Unlike the opiates, which cause drowsiness, cocaine gives its users energy.

Caffeine. Caffeine is a stimulant found in coffee, tea, chocolate, and cola drinks. It has been part of the human diet for many centuries and is one of the most widely used central nervous system stimulants in the world. In recent years, researchers have raised questions about possible risks associated with high caffeine intake, but no definite conclusions have been reached about the harmfulness of moderate amounts. However, some experts consider drinking large amounts of coffee or cola beverages evidence of a true addiction to caffeine.

Nicotine. Nicotine, the active ingredient in tobacco, is highly addictive, and cigarette smoking is among the most difficult habits for people to break. Many societies throughout the world have prized nicotine for

its mood-altering properties: it is said to produce either relaxation or arousal, depending on the user's state. Addiction to nicotine results in more than 400,000 premature deaths each year from smoking-related illnesses such as emphysema and lung cancer.

Withdrawal. Withdrawal symptoms are caused by psychological, physiological, and chemical reactions in the body that are brought on as the amount of the addictive chemical in the blood begins to fall. Abrupt withdrawal from alcohol can result in uncontrollable bodily shaking,

Crack users. Crack, a form of cocaine, is one of the most addictive drugs. *(Reproduced by permission of The Stock Market.)*

hallucinations, and seizures. Withdrawal from cigarettes can cause irritability and intense craving for nicotine. A coffee drinker may experience headaches and mood changes without the beverage. The hard drugs such as heroin and cocaine produce intense, sometimes violent, withdrawal symptoms. Abdominal pain, nausea, chills, tremors, sweating, hallucinations, and panic increase until eased by more of the same drug or treatment with medication to relieve the symptoms.

Nonchemical addictions

Gambling. Compulsive gambling begins with placing small bets on horses or playing low-stakes card games or craps. As the gambler experiences the exhilaration of winning, he or she engages in bigger, more frequent, and more irrational betting. Gamblers place ever-larger bets to make up for their losses and have been known to lose their jobs, their homes, and their families as a result of their addiction.

Work. Among addictions, no other is so willingly embraced than that of a workaholic, or a person addicted to work. On the surface, it might be difficult to tell if a person is a workaholic or just a hard and loyal worker. However, if work overshadows all other responsibilities in a worker's life, then the results can be telling. Focusing on work, workaholics tend to neglect their families, leaving the responsibility of raising their children solely to their spouses. All other social obligations are often neglected, as well. Finally, workaholics tend to neglect themselves, experiencing deteriorating health as they push themselves to the limit at work without regard for sleep or food. Counseling to identify the reason a person throws himself or herself into work is key for overcoming this addiction.

Internet. The Internet connects people all over the globe, exposing them to new cultures and offering vast amounts of information. But when the computer world begins to rival the real world, it becomes an addiction. Internet addiction insulates people from intimate settings and relationships. Some people would rather commune with a computer than with their spouses and children. Many marriages, families, and even promising careers at work have been lost because an individual has become addicted to the Internet. Since this is such a relatively new disorder, few self-help groups exist. Strangely enough, there are some on-line support groups designed to wean people from the Internet.

Others. Other compulsions or addictions include exercise, especially running. Running long distances triggers the release of morphinelike substances in the brain called endorphins, producing a feeling of euphoria or

happiness. This is the "high" that runners often describe. The high feels so good that the compulsive runner may engage in his hobby despite bad weather, injury, or social and family obligations. Excessive weight loss can also occur as a result of compulsive exercise.

The addict

The single characteristic common among all addicts—whether their addiction is chemical or nonchemical—is low self-esteem. Some experts believe that certain people are born with the predisposition (tendency) to become addicted to drugs or alcohol, particularly if one or both of the biological parents was a substance abuser. Social and psychological factors also may lead an individual to addiction. A desire to fit in, an attempt to relieve anxiety, an inability to cope with the stresses of daily life—all of these factors have been cited as possible springboards to addiction.

Treatment of addiction

Treatment of chemical addiction includes medical care of symptoms related to substance abuse and enrollment in a drug or alcohol rehabilitation program. In addition, participation in a self-help group such as Narcotics Anonymous or Alcoholics Anonymous can provide the emotional support an addict needs to stay away from drugs or alcohol. Psychological counseling and self-help groups can also be effective in treating nonchemical addictions.

It is often difficult to break the psychological and physical grip of addiction. Success depends upon the willingness of the addict to admit that a problem exists—and possession of the strength and determination to overcome it. Many former addicts have enough resolve to avoid drugs and alcohol for the rest of their lives, but studies show an equal number will take up the habit again.

[*See also* **Alcoholism; Cocaine; Eating disorders; Marijuana**]

Adhesives

Adhesives bond two or more materials at their surfaces. Any time you reattach a handle that has broken off a cup, paste a photograph into an album, or tape a message to a friend's door, you use an adhesive.

Natural adhesives such as beeswax, resin (tree sap), and bitumen (asphalt) have been used since earliest times. Ancient Egyptians used flour

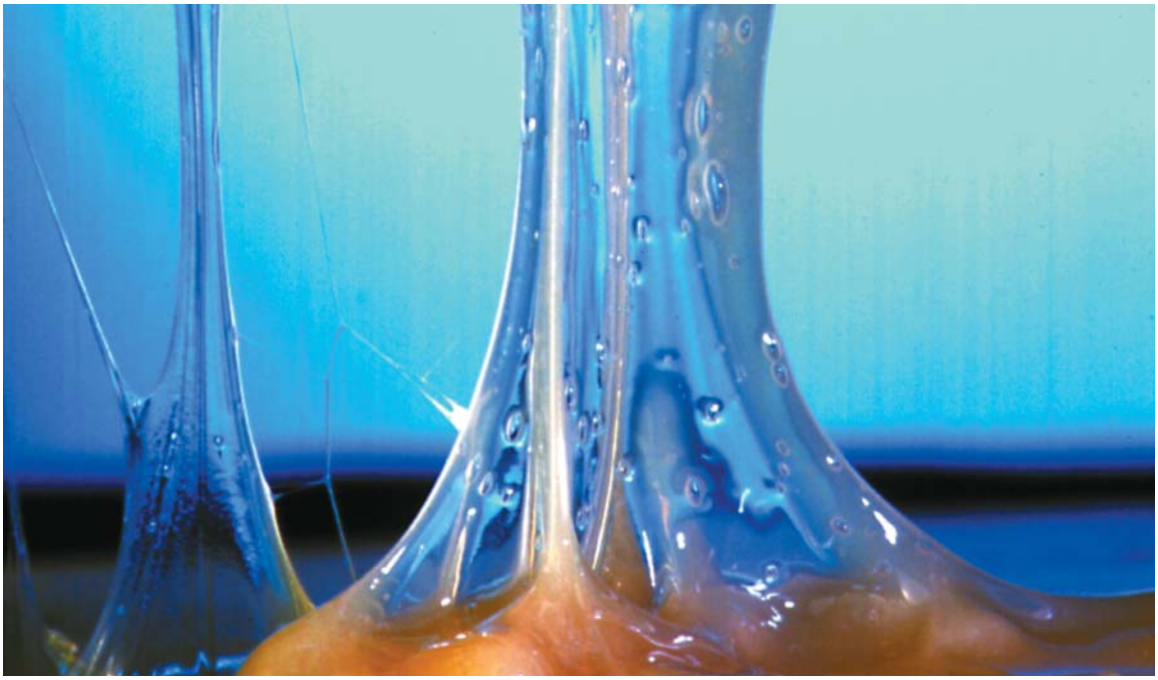
paste in the making of papyrus (reed paper) and glue made from animal skin and bones for woodworking. Monks of the Middle Ages (400–1450) used egg white to glue gold leaf to their illuminated (decorated) manuscripts.

Flour paste, animal glue, and egg white are examples of natural adhesives. Natural adhesives are still widely used but have been replaced for most applications by synthetic adhesives. Synthetic adhesives are compounds invented by chemists with special properties that make them useful for various kinds of bonding. For example, two metals can be bonded to each other using an epoxy resin, a type of plastic. Or metal can be bonded to wood using a rubberlike material known as neoprene.

New adhesives and new applications

Researchers are constantly looking for new kinds of adhesives and new ways to use them. For example, engineers at European Airbus, one of the world's largest manufacturers of airplanes, has found that plasticlike adhesives can be used to hold airplane sections together. The adhesives are cheaper and easier to use than traditional welds and rivets.

A better adhesive is not always a stronger adhesive. The material used on Post-it™ notes is an example. This adhesive is just strong enough



This colorless, waterproof adhesive is used for bonding wood. *(Reproduced by permission of Photo Researchers, Inc.)*

to hold a Post-it™ note to another piece of paper, wood, glass, or plastic. But it comes loose easily and can be reattached many times. Post-it™ notes were created in 1974 by Arthur Fry, a chemist at the Minnesota Mining and Manufacturing Company (3M). Fry made use of a "failed" discovery by a colleague who was trying to make a very strong adhesive, instead producing a very weak one.

One of the most widely used forms of adhesives is adhesive tape. Adhesive tape consists of an adhesive that has been attached to paper, cloth, rubber, plastic, or some other material. The familiar Scotch tape™ is perhaps the best known of all adhesive tapes. Scotch tape™ was invented in the 1920s by Richard Drew, another chemist at the 3M company. Drew found a way to coat Du Pont's newly invented cellophane tape with a thin layer of adhesive to make it the all-purpose aid present in most households today. Variations of the original Scotch tape™ in use today are carpet tape, masking tape, duct tape, and sealing tape.

Aerodynamics

Aerodynamics is the study of air flow over airplanes, cars, and other objects. Airplanes fly because of the way in which air flows over their wings and around their bodies, so a knowledge of aerodynamics is crucial to the design and construction of airplanes. The efficiency with which automobiles use fuel is also a function of air flow. Even stationary objects are affected by aerodynamics. Winds blowing past a tall building, for example, may cause windows to pop out if they are not properly designed and installed.

Factors affecting air flow

Four properties of air affect the way in which it flows past an object: viscosity, density, compressibility, and temperature. Viscosity is the resistance of a fluid to flow. Molasses is very viscous because is flows slowly, while water is less viscous because it flows readily. The viscosity of air is important in aerodynamics because air tends to stick to any surface over which it flows, slowing down the motion of the air.

The density and compressibility of air are important factors at high speeds. As an object travels rapidly through air, it causes air to become compressed and more dense. As a result, other properties of air then change.

The effects of temperature change on air flow also become important at high speeds. A regular commercial airplane, after landing, will feel

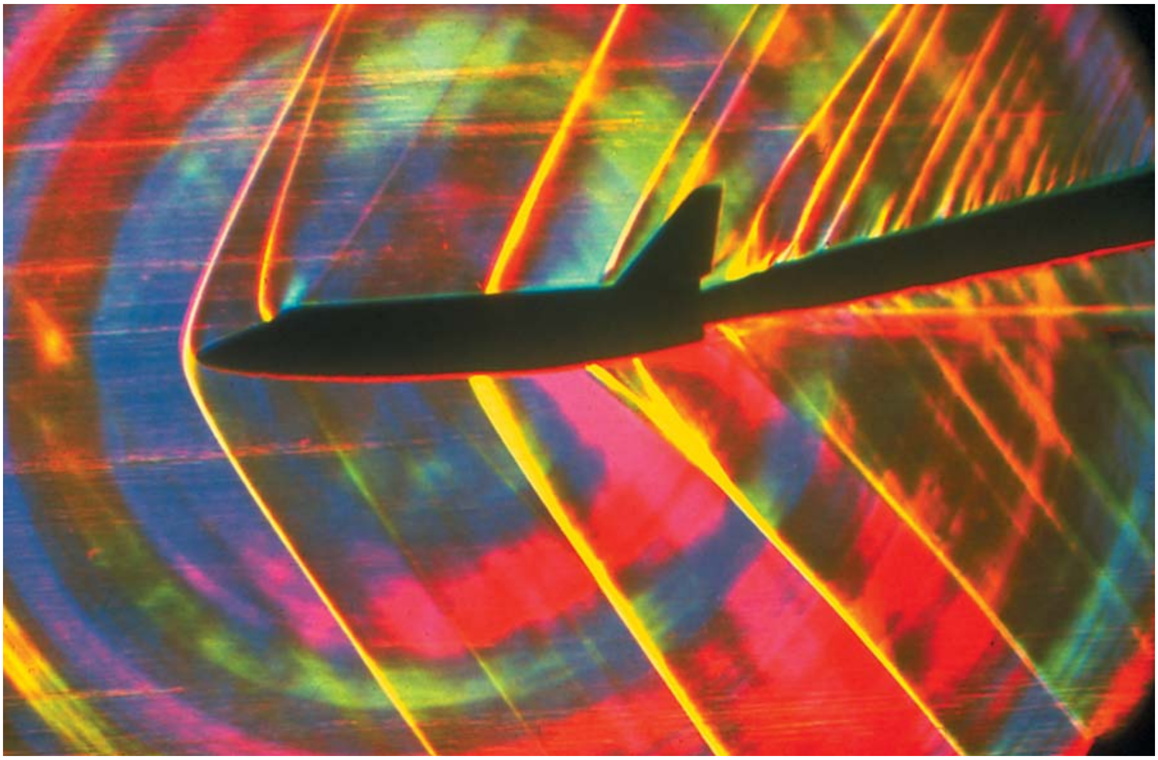
cool to the touch. But the Concorde jet, which flies at twice the speed of sound, will feel hotter than boiling water.

Laminar and turbulent flow

Air can travel over a surface following patterns of flow referred to as either laminar or turbulent. In laminar or streamlined flow, air moves with the same speed in the same direction at all times. The flow appears to be smooth and regular. Bernoulli's principle applies during laminar flow. Bernoulli's principle states that a fluid (such as air) traveling over the surface of an object exerts less pressure than if the fluid were still. Airplanes fly because of Bernoulli's principle. When an airplane takes off, air rushes over the top surface of its wing, reducing pressure on the upper surface of the wing. Normal pressure below the wing pushes the wing upward, carrying the airplane upward along with it.

Turbulent flow is chaotic and unpredictable. It consists of irregular eddies (circular currents) of air that push on a surface in unexpected ways. The bumpy ride you may have experienced on a commercial airplane could have resulted from the development of turbulent flow over the airplane's wings.

A model aircraft being tested in a wind tunnel. *(Reproduced by permission of Photo Researchers, Inc.)*



Words to Know

Airfoil: The cross section of an airplane wing parallel to (or running in the same direction as) the length of the plane.

Angle of attack: The angle that the length of the airfoil forms with an oncoming airstream.

Camber: The additional curvature of the upper surface of the airfoil relative to the lower surface.

Induced drag: Also known as drag due to lift; the drag on the airplane due to vortices (whirling patterns of air) on the wingtips.

Stall: A sudden loss of lift on the airplane wing when the angle of attack increases beyond a certain value.

Supersonic speed: A speed greater than that of sound.

Skin friction and pressure drag

Drag is any force that tends to prevent an object from moving forward. One source of drag in airplanes and automobiles is skin friction. As air passes over the surface of either vehicle, friction between air and surface tends to slow the plane or automobile down. One of the goals of transportation engineers is to find a shape that has the least amount of skin friction, thus reducing the amount of drag on the vehicle. Sleek, teardrop-shaped cars became popular in the middle to late 1990s because they had so little skin friction.

Engineers also work to reduce pressure drag. Pressure drag is caused by abrupt changes in the shape of a car or airplane. The point at which the roof of a car ends, as an example, is a point of high pressure drag. A car designed with a smooth transition from roof to trunk will have less pressure drag and, therefore, will travel more smoothly.

Airfoil

An airfoil is a two-dimensional cross section of the wing of an airplane as viewed from the side. Engineers seek to design airfoils that will have the greatest amount of lift and the least amount of drag. One factor important in the design of an airfoil is the curvature, or camber, of the upper side of the wing. The greater the camber, the faster air moves over

Bernoulli's Principle

What do jet airplanes and a baseball pitcher's curveball have in common? They both depend on Bernoulli's principle for their operation. Bernoulli's principle states that the faster a fluid (such as air or water) flows over a surface, the less pressure the fluid exerts on that surface.

In the case of the jet airplane, air travels faster over the top of the wing than across the bottom of the wing. Since the pressure on top of the wing is reduced, the airplane is pushed upward. A pitcher can cause a baseball to curve by making it spin. On one side of the ball, air carried along by the spinning ball rushes past in the same direction the ball is traveling. On the other side of the ball, air is pushed in the opposite direction. On the side of the ball where air is traveling faster, pressure is reduced. Higher air pressure on the opposite side of the ball pushes it out of a straight path, causing it to curve.

the upper surface and the greater the lift to the wing. The amount of camber in a wing is changed by means of flaps and slats in the wing that produce different amounts of lift during take-off, cruise, and landing.

Another factor affecting lift is the angle of attack: the position of the wing in comparison to the ground. As the forward edge of the wing is tipped downward, the amount of lift on the wing is increased. Increasing the angle of attack too much, however, may result in a sudden loss of lift, causing the airplane to lose all lift and go into a stall.

Induced drag

Air movement around an airplane wing can also cause drag effects. At the very tip of the wing, air traveling above and below the wing meet and produce whirlpool-like patterns known as vortices. These vortices tend to pull the wing downward, thus producing drag forces on the wing. These forces are known as induced drag.

Stability and control

Aerodynamics is applied to other problems of air flight as well. Airplanes have tendencies to rotate in one of three directions: in a horizontal back-and-forth motion around the center of the airplane, in a front-over-back motion, or in a rolling fashion, wing-over-wing. Special

controls must be developed to prevent loss of control in any of these directions, any one of which could cause the airplane to crash. Ailerons (pronounced AYL-uh-ronz) are one such control. They prevent a rolling action by increasing the lift on one wing while decreasing it on the other.

Supersonic flight

Flight at speeds greater than that of sound present special problems for engineers. One reason is the importance of the compressibility of air at these speeds. Sound waves produced by an aircraft moving through the air travel more slowly than the aircraft itself. This produces a shock wave characterized by an abrupt change in temperature, pressure, and density that causes a steep increase in the drag and loss of stability of the aircraft. The loud sonic boom one hears is the wave hitting Earth's surface.

The need to overcome the effects of shock waves has been a major problem for engineers. Swept-back wings are one way of reducing the effects of shock. The delta or triangular wings of the supersonic Concorde and several military airplanes are another solution. The most advanced airplane designs actually call for the complete retraction of the wings during the fastest part of a flight, converting them into a rocket for part of the trip.

[*See also* **Aircraft; Balloon; Fluid dynamics**]

An aerosol spray can. *(Reproduced by permission of Field Mark Publications.)*

Aerosols

Aerosols are collections of tiny particles of solid and/or liquid suspended in a gas. The size of particles in an aerosol ranges from about 0.001 to about 100 microns. (A micron is one-millionth of a meter.) The most familiar form of an aerosol is the pressurized spray can, which can dispense anything from hair spray to enamel paint to whipping cream. Aerosols are produced by a number of natural processes and are now manufactured in large quantities for a variety of commercial uses. They are also at the root of a number of environmental problems, including air pollution and destruction of ozone, a natural component of Earth's atmosphere.

Classification

Aerosols are commonly classified into various subgroups based on the nature and size of the particles of which they are composed and, to some extent, the manner in which the aerosol is formed. Although relatively strict scientific definitions are available for each subgroup, these distinctions may become blurred in actual practical applications. The most important of these subgroups are fumes, dusts, mists, and sprays.

Fumes. Fumes consist of solid particles—ranging in size from 0.001 to 1 micron—suspended in a gas. Probably the most familiar form of a fume is smoke. Smoke is formed from the incomplete combustion of fuels such as coal, oil, or natural gas. The particles that make up smoke are smaller than 10 microns in size.

Dusts. Dusts also contain solid particles suspended in a gas, usually air, but the particles are larger in size than those in a fume. They range from about 1 to about 100 microns in size, although they may be even larger. Dust is formed by the release of materials such as soil and sand, fertilizers, coal dust, cement dust, pollen, and fly ash into the atmosphere. Because of their larger particle size, dusts tend to be more unstable and settle out more rapidly than do fumes, which do not settle out at all.

Mists. Mists are liquid particles—less than about 10 microns in size—dispersed in a gas. The most common type of mist is that formed by tiny water droplets suspended in the air, as on a cool summer morning. If the concentration of liquid particles becomes high enough to affect visibility, it is then called a fog. A particular form of fog that has become significant in the last half century is smog. Smog forms when natural moisture in the air interacts with human-produced components, such as smoke and other combustion products, to form chemically active materials.

Sprays. Sprays form when relatively large (10+ microns) droplets of a liquid are suspended in a gas. Sprays can be formed naturally, as along an ocean beach, but are also produced as the result of some human inventions such as aerosol can dispensers of paints, deodorants, and other household products.

Sources

About three-quarters of all aerosols found in Earth's atmosphere come from natural sources. The most important of these natural components are sea salt, soil and rock debris, products of volcanic emissions, smoke from forest fires, and solid and liquid particles formed by chemical reactions in the atmosphere.

Words to Know

Acid rain: A form of precipitation that is significantly more acidic than neutral water, often produced as the result of industrial processes.

Chlorofluorocarbons (CFCs): A group of organic compounds once used widely as propellants in commercial sprays but regulated in the United States since 1987 because of their harmful environmental effects.

Dust: An aerosol consisting of solid particles in the range of 1 to 100 microns suspended in a gas.

Electrostatic precipitator: A device for removing pollutants from a smokestack.

Fume: A type of aerosol consisting of solid particles in the range 0.001 to 1 micron suspended in a gas.

Micron: One-millionth of a meter.

Mist: A type of aerosol consisting of droplets of liquid less than 10 microns in size suspended in a gas.

Ozone layer: A region of the upper atmosphere in which the concentration of ozone is significantly higher than in other parts of the atmosphere.

Smog: An aerosol form of air pollution produced when moisture in the air combines and reacts with the products of fossil fuel combustion.

Smoke: A fume formed by the incomplete combustion of fossil fuels such as coal, oil, and natural gas.

Spray: A type of aerosol consisting of droplets of liquid greater than 10 microns in size suspended in a gas.

Stack gases: Gases released through a smokestack as the result of some power-generating or manufacturing process.

Volcanic eruptions are major, if highly irregular, sources of atmospheric aerosols. The eruptions of Mount Hudson in Chile in August 1991 and Mount Pinatubo in the Philippines in June 1991 produced huge volumes of aerosols that had measurable effects on Earth's atmosphere.

The remaining atmospheric aerosols result from human actions. Some, such as the aerosols released from spray-can products, go directly to form aerosols in the atmosphere. Others undergo chemical changes; for

example, oxides of nitrogen and sulfur are produced during the combustion of fossil fuels such as coal and oil. These oxides may be converted to liquid or solid nitrates and sulfates, which are then incorporated into atmospheric aerosols.

Physical properties

The physical and chemical properties of an aerosol depend to a large extent on the size of the particles that make it up. When those particles are very large, they tend to have the same properties as a macroscopic (large size) sample of the same material. The smaller the particles are, however, the more likely they are to take on new characteristics different from those of the same material in bulk.

Aerosols tend to coagulate, or to collide and combine with each other to form larger bodies. A cloud, for example, consists of tiny droplets of water and tiny ice crystals. These particles move about randomly within the cloud, colliding with each other from time to time. As a result of a collision, two water particles may adhere (stick) to each other and form a larger, heavier particle. This process results in the formation of droplets of water or crystals of ice heavy enough to fall to Earth as rain, snow, or some other form of precipitation.

Synthetic production

The synthetic production of aerosols for various commercial purposes has become such a large industry that the term aerosol has taken on a new meaning. Average citizens who know little or nothing about the scientific aspects of aerosols recognize the term as referring to devices for dispensing a wide variety of products, including hair spray, furniture polish, and spray paint.

The concept of aerosol technology is relatively simple. A spray can is filled with a product to be delivered (such as paint), a propellant, and sometimes a carrier to help disperse the product. Pressing a button on the can releases a mixture of these components in the form of an aerosol.

Most aerosols, however, are actually more complex than this simple description. An aerosol pesticide, for example, must be formulated in such a way that a precise amount of poison is released, enough to kill pests, but not so much as to produce an environmental hazard. Similarly, an aerosol throat spray must deliver a carefully measured quantity of medication.

The production of commercial aerosols fell slightly in the late 1980s because of concerns about the ozone (see Environmental factors below)

and other environmental effects. By 1992, however, their manufacture had rebounded. In that year 990 million container units (bottles and cans) of personal aerosol products and 695 million container units of household products were manufactured.

Combustion aerosols

Aerosol technology has made possible vastly improved combustion systems, such as those used in fossil-fueled power generator plants and in rocket engines. The fundamental principle involved is that any solid or liquid fuel burns only at its surface. The combustion of a lump of coal proceeds relatively slowly because inner parts of the coal cannot begin to burn until the outer layers are burned off first.

The rate of combustion can be increased by dividing a lump of coal or a barrel of fuel oil into very small particles, the smaller the better. Power-generating plants today often run on coal that has been pulverized to a dust or on oil that has been converted to a mist. The dust or mist is then thoroughly mixed with an oxidizing agent, such as air or pure oxygen, and fed into the combustion chamber. The rate of combustion of such aerosols is many times greater than would be the case for coal or oil in bulk.

Environmental factors

A number of environmental problems have been connected to aerosols, the vast majority of them associated with aerosols produced by human activities. For example, smoke released during the incomplete combustion of fossil fuels results in the formation of at least two major types of aerosols that may be harmful to plant and animal life. One type consists of finely divided carbon released from unburned fuel. This soot can damage plants by coating their leaves and reducing their ability to carry out photosynthesis (using light to break down chemical compounds). It can also clog the alveoli—air sacs in human lungs—and interfere with a person's respiration.

A second type of harmful aerosol is formed when smokestack gases, such as sulfur dioxide and nitrogen oxides, react with oxygen and water vapor in the air to form sulfuric and nitric acids, respectively. Mists containing these acids may be carried hundreds of miles from their original source before conglomeration occurs and the acids fall to Earth as acid rain. Considerable disagreement exists about the precise nature and extent of the damage caused by acid rain. But there seems to be little doubt that in some locations it has caused severe harm to plant and aquatic life.

Ozone depletion. A particularly serious environmental effect of aerosol technology has been damage to Earth's ozone layer. This damage appears to be caused by a group of compounds known as chlorofluorocarbons (CFCs) which, for more than a half century, were by far the most popular of all propellants used in aerosol cans.

Scientists originally felt little concern about the use of CFCs in aerosol products because they are highly stable compounds at conditions encountered on Earth's surface. They have since learned, however, that CFCs behave very differently when they diffuse into the upper atmosphere and are exposed to the intense solar radiation present there.

Under those circumstances, CFCs decompose and release chlorine atoms that, in turn, react with ozone in the stratosphere (the atmospheric region approximately 7 to 31 miles above Earth's surface). As a result, the concentration of ozone in portions of the atmosphere has been steadily decreasing. This change could prove to be very dangerous, since Earth's ozone layer absorbs ultraviolet radiation from the Sun and protects living things on our planet from the harmful effects of that radiation.

Technological solutions. Methods for reducing the harmful environmental effects of aerosols such as those described above have received the serious attention of scientists for many years. Consequently, a number of techniques have been invented for reducing the aerosol components of things like stack gases. One device, the electrostatic precipitator, is based on the principle that the particles of which an aerosol consists (such as unburned carbon in stack gases) carry small electrical charges. By lining a smokestack with charged metal grids, the charged aerosol particles can be attracted to the grids and pulled out of the emitted smoke.

Efforts aimed at solving the CFC/ozone problem have not yet been as successful as those used to combat other forms of air pollution. Chemists have developed and tested a number of substitutes for CFCs as aerosol propellants. One group of special interest has been the hydrochlorofluorocarbons (HCFCs), CFC-like compounds that also contain hydrogen atoms. Most CFC-substitutes tried so far, however, are very expensive, not efficient enough as a propellant, or equally harmful to the environment.

The dangers of aerosol sniffing

Another risk associated with commercial aerosols is their use as recreational drugs. Inhalation of some consumer aerosol preparations may produce a wide variety of effects, including euphoria, excitement, delu-

sions, and hallucinations. Repeated sniffing of aerosols can result in addiction that can cause intoxication, damaged vision, slurred speech, and diminished mental capacity.

[*See also* **Acid rain; Pollution; Ozone**]

Africa

Africa is the world's second largest continent, encompassing an area of 11,677,240 square miles (30,244,051 square kilometers), including offshore islands. Recognized as the birthplace of the human race and of many other animal and plant species, it also possesses the world's richest and most concentrated deposits of minerals such as gold, diamonds, uranium, chromium, cobalt, and platinum.

Origin of Africa

Geologically, Africa is 3.8 billion years old (Earth is 4.6 billion years old). Present-day Africa, occupying one-fifth of Earth's land surface, is the central remnant of the ancient southern supercontinent called Gondwanaland, a landmass once made up of South America, Australia, Antarctica, India, and Africa. This massive supercontinent broke apart between 195 million and 135 million years ago, split by the same geological forces—continental drifting, earthquakes, volcanos—that continue to transform Earth's crust today.

General features

Africa has fewer high peaks than any other continent and few extensive mountain ranges. The major ranges are the Atlas Mountains along the northwest coast and the Drakensberg Mountains in South Africa. The highest point on the continent is Kibo (19,340 feet/5,895 meters), a peak of Mount Kilimanjaro in northeast Tanzania. Despite its location near the equator, the peak is permanently snowcapped.

Geologists characterize Africa's topography (physical features) as a collection of swells and basins. Swells are layers of rock warped upward by Earth's internal heat and pressure. Basins are broad, lower-lying areas between swells. The continent can be visualized as an uneven tilted plateau, one that slants down toward the north and east. The swells are highest in East and central West Africa, where they are capped by volcanic flows originating from the Great Rift Valley.

Africa

AFRICA
INDIAN
OCEAN
ATLANTIC
OCEAN
Red Sea
Gulf of Aden
Mozambique Channel
MOROCCO
ALGERIA
TUNISIA
LIBYA
EGYPT
SUDAN
CHAD
NIGER
MALI
MAURITANIA
WESTERN SAHARA (Occupied by Morocco)
SENEGAL
THE GAMBIA
GUINEA-BISSAU
GUINEA
SIERRA LEONE
LIBERIA
CÔTE D'IVOIRE
BURKINA FASO
GHANA
TOGO
BENIN
NIGERIA
CAMEROON
CENTRAL AFRICAN REPUBLIC
EQUATORIAL GUINEA
SÃO TOMÉ & PRINCIPE
GABON
REPUBLIC OF THE CONGO
DEMOCRATIC REPUBLIC OF THE CONGO
ANGOLA
ANGOLA (Cabinda)
ERITREA
DJIBOUTI
ETHIOPIA
SOMALIA
KENYA
UGANDA
RWANDA
BURUNDI
TANZANIA
MALAWI
ZAMBIA
MOZAMBIQUE
ZIMBABWE
NAMIBIA
BOTSWANA
SOUTH AFRICA
SWAZILAND
LESOTHO
MADAGASCAR
COMOROS
SEYCHELLES
MAURITIUS
CAPE VERDE
Aozou Strip
Cairo
Khartoum
Addis Ababa
Nairobi
Mogadishu
Dar es Salaam
Kinshasa
Luanda
Lusaka
Harare
Windhoek
Gaborone
Pretoria
Maputo
Antananarivo
Tripoli
Tunis
Algiers
Rabat
Dakar
Abuja
Accra
Niamey
Bamako
Nouakchott

Great Rift Valley

The most distinctive and dramatic geological feature in Africa is the Great Rift Valley. The rift opened up approximately 65 million years ago, shortly after the dinosaurs became extinct. It extends almost 3,000 miles (4,830 kilometers) from northern Syria down the eastern side of the African continent to central Mozambique. The ranges in elevation of the valley are great, from about 1,300 feet (395 meters) below sea level at the Dead Sea to over 6,000 feet (1,830 meters) above sea level in southern Kenya.

The Great Rift Valley has a western branch that begins north of Lake Albert (Lake Mobutu) along the Zaire-Uganda border. It then curves south along Zaire's eastern border, forming that country's boundary with Burundi. This branch is punctuated by a string of lakes, the deepest being Lake Tanganyika (on the boundary between Tanzania and Zaire), with a maximum depth of 4,710 feet (1,436 meters).

The rift valley is alive seismically, with much earthquake-related activity occurring. About once a decade lava flows and volcanic eruptions take place in the Virunga mountain range on the Zaire-Uganda border. The main or eastern branch of the rift valley experiences more volcanic and seismic activity than the western branch. Geologists consider the geological forces driving the main branch to be those associated with the origin of the entire rift valley and deem the main branch to be the older of the two.

Human evolution

Hominids, or human ancestors, arose in the Great Rift Valley. Paleontologists, scientists who study fossil remains, have unearthed in Ethiopia and Tanzania hominid fossils that have been dated from three to four million years old. Hominid remains have also been found in Morocco, Algeria, and Chad.

Volcanic activity outside the Great Rift Valley

Mount Cameroon, which stands 13,350 feet (4,005 meters), and a few smaller neighboring volcanos in Cameroon on the Gulf of Guinea are the only active volcanos on the African mainland outside of the Great Rift Valley. However, extinct volcanos and evidence of their activity are widespread on the continent. The Ahaggar Mountains in the central Sahara Desert contain more than 300 volcanic necks, massive vertical columns of volcanic rock, that rise 1,000 feet (305 meters) or more. Also in the central Sahara, several hundred miles to the east in the Tibesti Mountains,

Opposite page: Africa. *(Reproduced by permission of The Gale Group.)*

Words to Know

Basins: Broad, lower-lying areas between swells.

Deforestation: Total clearing of trees and other plants from forest areas.

Desertification: Transformation of arid or semiarid productive land into desert.

Gondwanaland: Ancient supercontinent that was made up of present-day Africa, South America, Australia, Antarctica, and India.

Swells: Layers of rock warped upward by Earth's internal heat and pressure.

Volcanic neck: A massive vertical column of volcanic rock, formed in the vent of a volcano, that has been exposed by erosion of the flanks of the volcano.

there exist huge volcanic craters or calderas. In the Great Rift Valley, the Ngorongoro Crater in Tanzania, surrounded by teeming wildlife and spectacular scenery, is a popular tourist attraction. Volcanism formed the diamonds found in South Africa and Zaire. The Kimberly diamond mine in South Africa is actually an ancient volcanic neck.

Origin of Sahara Desert

Between 1,600,000 and 11,000 years ago, the Sahara was subjected to humid and then to arid (dry) phases, causing it to spread into adjacent forests and green areas. About 5,000 to 6,000 years ago, further humid and arid phases promoted desertification (the transformation of arid or semiarid land into desert) in the Sahara as well as the Kalahari in southern Africa. Earth scientists say the expansion of the Sahara is still occurring today, with the desertification of farm and grazing land responsible for the spread of famine in the Sahel or Saharan region.

Minerals and resources

Africa holds the world's richest concentration of minerals and gems. In South Africa, the two-billion-year-old Bushveld Complex, one of Earth's largest masses of igneous rock (cooled and hardened molten rock),

contains major deposits of metals such as platinum, chromium, and vanadium. These metals are indispensable in toolmaking and high-tech industrial processes. Almost all of the world's chromium reserves are found in Africa. Chromium is used to harden alloys (metal mixtures), to produce stainless steels, and to provide resistance to corrosion.

As for other minerals, one-half of the world's cobalt is in Zaire. One-quarter of the world's aluminum ore is found in a coastal belt of West Africa stretching 1,200 miles (1,920 kilometers) from Guinea to Togo, with the largest reserves in Guinea. Uranium deposits are found in South Africa, Niger, Gabon, Zaire, and Namibia. South Africa alone contains one-half the world's gold reserves. Mineral deposits of gold are also found in Zimbabwe, Zaire, and Ghana.

Kimberlite pipes—vertical, near-cylindrical rock bodies caused by deep melting in the upper mantle of Earth's crust—are the main source of gem and industrial diamonds in Africa. Africa contains 40 percent of

Kibo, a peak of Mount Kilimanjaro in Tanzania, is the highest point in Africa, at 19,340 feet (5,895 meters). *(Reproduced by permission of JLM Visuals.)*

the world's diamond reserves, which are located in South Africa, Botswana, Namibia, Angola, and Zaire.

Major coal deposits exist across northern and southern Africa and in the central African countries of Zaire and Nigeria. Petroleum reserves are high in northern Africa, particularly in Libya, Algeria, Egypt, and Tunisia. Nigeria is the biggest petroleum producer in West Africa, followed by Cameroon, Gabon, and the Congo. Angola contains the chief petroleum reserves in southern Africa.

Modern-day climatic and environmental factors

The impact of humankind upon the African environment has been far-reaching and undeniable. Beginning 2,000 years ago and accelerating to the present day, belts of African woodlands have been cleared of trees and other forest plants, a process known as deforestation. Such environmental destruction has been worsened by the overgrazing of animals and other agricultural abuses. Human-made climate changes, including possible global warming caused by the buildup of human-made carbon dioxide, chlorofluorocarbons (CFCs), and other greenhouse gases, have also damaged the environment.

Deforestation, desertification, and soil erosion pose threats to Africa's artificial lakes and, thereby, the continent's hydroelectric capacity, or ability to produce electricity with water power. Africa has limited water resources, and its multiplying and undernourished populations exert ever-greater demands on farmland that has to be irrigated. Many earth scientists say using more environmentally friendly farming techniques and practicing population control are vital to stabilizing Africa's ecology and protecting its resources and mineral wealth.

Agent Orange

Agent Orange is one of several herbicidal (plant-killing) preparations that was used by the U.S. military to destroy forests and enemy crops in Vietnam in the 1960s. Agent Orange was created by mixing equal quantities of two agricultural herbicides commonly used to kill weeds: 2,4-D and 2,4,5-T. Present in the 2,4,5-T as an impurity was 2,3,7,8-tetrachlorodibenzo-p-dioxin (usually abbreviated to TCDD), a dioxin contaminant that is highly toxic to some animals. (Dioxin is a term used collectively for a group of chemical by-products of papermaking and other manufacturing processes.)

Words to Know

Chloracne: A rash of skin lesions on the face, neck, and back caused by exposure to TCDD.

Herbicide: A chemical substance used to destroy or inhibit plant growth.

Hodgkin's disease: A type of cancer characterized by enlargement of the lymph nodes, spleen, and liver and with accompanied weight loss, heavy sweating, and itching of the skin.

Mangrove: Tropical coastal trees or shrubs that produce many supporting roots and that provide dense vegetation.

Non-Hodgkin's lymphoma: Tumors that develop from cells in lymph nodes, bone marrow, spleen, liver, or other sites in the body.

Soft-tissue sarcoma: A rare but varied group of tumors that arise in the muscles, connective tissue, inner layer of skin, bone, and other tissues.

Toxicity: The degree to which a chemical, in sufficient quantities, can poison humans and other organisms.

History

During the Vietnam War (1961–75; a civil war between the communist North and the democracy-seeking South), North Vietnamese guerrillas found cover in the lush jungles of South Vietnam. To deprive their opponents of hiding places and food crops, the U.S. military instituted a program called Operation Ranch Hand, which involved the aerial spraying of herbicides. Ground spraying from boats, trucks, and backpacks occurred as well. In all, U.S. troops sprayed approximately 19 million gallons (72 million liters) of Agent Orange and other herbicides over 4 million acres (1.6 million hectares). This military strategy is thought to have saved the lives of many U.S. combat soldiers who had been sent to fight on behalf of the South Vietnamese.

Concerns arise over health effects

Concerns about the health effects of exposure to Agent Orange were initially voiced in 1970, following a study that reported the incidence of birth defects in laboratory mice given high doses of the herbicide

2,4,5-T. TCDD, a dioxin contaminant of 2,4,5-T, was isolated as the actual cause of the birth defects. A commission established in 1970 to study the effects of herbicides on the ecology and population of South Vietnam reported that herbicides had not only destroyed vegetation and food, but 2,4,5-T and its associated dioxin contaminant might possibly have caused birth defects among South Vietnamese people who were exposed to it.

On April 15, 1970, all use of 2,4,5-T in the United States was suspended, except for the killing of weeds and brush on non-crop land. On May 9, 1970, Operation Ranch Hand flew its last mission in Vietnam, and U.S. forces stopped ground spraying in 1971. The herbicide was banned completely in 1985 by the Environmental Protection Agency.

Toxicity of TCDD. TCDD is a by-product of the manufacture of trichlorophenol, a chemical used to produce 2,4,5-T. Workers involved in accidents or spills at factories where the herbicide 2,4,5-T is manufactured have developed a condition called chloracne, a rash of skin lesions on the face, neck, and back. After researchers developed a method to produce trichlorophenol with a reduced level of TCDD as a by-product, the number of chloracne cases among factory workers in the herbicide industry decreased substantially.

The toxicity of the dioxin contaminant TCDD is the subject of continuing controversy and study. While some animals are very sensitive to TCDD, others are more tolerant to it. A very small amount can kill 50 percent of guinea pigs exposed to it, but a dose thousands of times larger is needed to cause the same number of deaths in hamsters.

Investigation of health effects

Serious health symptoms reported in 1977 by veterans of the Vietnam War spurred both the White House and the Veterans Administration (VA) to institute studies to evaluate the possible long-term health effects of herbicides and contaminants.

Exposure to TCDD in humans is measured by the amount of the contaminant found in blood and fatty tissue, where it tends to accumulate. Studies determined that levels of TCDD in the blood of chemical plant workers were strongly related to length of time of exposure.

Inadequate records of herbicide spraying and troop movements have made it difficult to determine to what degree individuals were exposed to herbicides and TCDD in Vietnam. Ranch Hand personnel who were heavily exposed to Agent Orange had significantly higher TCDD levels than

other veterans. The average TCDD concentrations of Vietnam veterans who might have been exposed to Agent Orange on the ground did not differ significantly from that of other veterans and civilians.

The Agent Orange Act of 1991, passed by the U.S. Congress, ordered the National Academy of Sciences (NAS) to review and evaluate information regarding the health effects of exposure to Agent Orange and its components. Lacking enough information about the levels of herbicide exposure among Vietnam veterans to make any conclusions

U.S. Air Force planes spray Agent Orange over the South Vietnamese countryside in 1966. *(Reproduced by permission of AP/Wide World Photos.)*

regarding health effects, the NAS instead reviewed existing studies of people known to have been exposed to herbicides. In 1993, the 16-member panel of experts classified possible health effects in four categories, depending on the degree to which they could be associated with TCDD exposure.

In a 1996 update, the Institute of Medicine (IOM) reported new evidence upholding the 1993 finding of sufficient evidence of an association between TCDD exposure and various disorders with symptoms including tumors and skin lesions, including soft-tissue sarcoma, non-Hodgkin's lymphoma, Hodgkin's disease, and chloracne. Porphyria cutanea tarda (a rare skin disease) was downgraded from sufficient to "limited/suggestive evidence of an association," a category that also includes prostate cancer, multiple myeloma (cancer of bone marrow cells), and respiratory cancers (cancers of the lung, larynx, or trachea).

The IOM also reported there was new "limited/suggestive evidence" to show an association between TCDD exposure and the congenital birth defect spina bifida (incomplete closure of the spinal column at birth) in Vietnam veterans' children. A neurological disorder suffered by veterans was also placed in this category. The remaining two categories include cancers or disorders that have insufficient or no evidence of an association with TCDD exposure.

Ecological effects

The damage to the plant life of South Vietnam caused by the spraying of Agent Orange is still visible today. The most severe damage occurred in the mangrove forests (tropical trees and shrubs) of coastal areas where spraying left barren, badly eroded coastlines. The number of coastal birds declined dramatically, and with the disappearance of the web of water channels beneath the mangrove trees, fish were deprived of important breeding grounds. It is estimated that full recovery of the mangrove forests to their former state will take at least 100 years.

The loss of commercially useful timber due to aerial spraying of Agent Orange over dense inland forests was significant. About 10 percent of the tall trees making up the forest canopy were killed. Smaller shrubs now comprise the majority of vegetation in affected areas. Tussock grasses and bamboo replaced woody plants destroyed by the spraying. The beginnings of natural recovery can be seen, but it will be many years before the forests will approach their former productivity.

As the rich, diverse tropical forests disappeared, so did animal habitats. As a result, the number of bird and mammal species living in the ar-

eas that were sprayed declined dramatically. Wild boar, wild goat, water buffalo, tiger, and various species of deer became less common once the cover and food resources of the forest were removed. Domestic animals such as water buffalo, zebus (an Asian ox), pigs, chickens, and ducks were also reported to become ill after the spraying of Agent Orange.

The contaminant TCDD is not easily or quickly broken down in soil, and there is concern that herbicide residues might inhibit the growth of crops and other plants. These by-products, which can be toxic, could then be passed to humans through the food chain.

[*See also* **Agrochemical**]

Aging and death

Aging is a series of biological changes that follow a natural progression from birth through maturity to old age and death. For most people, advancing age is characterized by graying or thinning hair, loss of height, wrinkling of the skin, and decreased muscular strength. Still, an active lifestyle, including both exercise and sound nutrition, can contribute greatly to achieving a long and productive life. Genetics (inherited physical characteristics) also appears to play a role in the process of aging and death. People whose parents or grandparents live to old age seem to have a better chance of living long lives themselves.

Great strides have been made in increasing the average life expectancy in humans in the United States. This is due largely to the elimination of many diseases of early childhood and young adulthood and to the advanced methods of treating diseases that in the past would have resulted in early death. However, the maximum potential life span (how long an organism can exist) of humans appears to remain the same—about 85 years—regardless of efforts to expand it.

Every species has a different normal life span. In most species, death occurs not long after the reproductive phase of life ends. This is obviously not the case for humans. However, women do experience physical changes when they are past their childbearing years. Levels of the hormone estrogen begin to fall, which results in the gradual cessation, or stopping, of menstruation. (Hormones are chemicals produced by the body that regulate various bodily functions. Menstruation is the monthly shedding of the lining of the uterus [womb] in nonpregnant females.) After menopause (when menstruation ceases and childbearing is no longer possible), women produce less facial skin oil (which leads to wrinkling) and

are at greater risk of developing osteoporosis (brittle bones). Men continue to produce nearly the same levels of facial oils and are thus less prone to early wrinkling.

Effects of aging

As we age, our cells become less efficient and our bodies become less able to carry out their normal functions. Muscles lose strength, hearing and vision become less acute, reflex times slow down, lung capacity decreases, and the heart's ability to pump blood may be affected. In addition, the immune system weakens, making it less able to fight infection and disease.

Theories on aging

No single theory on how and why people age is able to account for all aspects of aging, but most take one of two approaches: (1) that humans are genetically programmed to age and die, and (2) that natural wear and tear causes aging and eventual death. Arguments in favor of genetic programming cite hormonal control and/or limited cell division (reproduction) as the mechanisms involved in the aging process. One hormonal approach focuses on the hypothalamus (at the base of the forebrain), which controls the production of growth hormones (which influence growth and development) in the pituitary gland. It is thought that—possibly due to the action of a hormonal clock—the hypothalamus either slows down normal hormonal function or that it becomes more error-prone with time, leading to physiological aging.

Repeated experiments have shown that human cells grown in tissue culture in the laboratory will divide only about 50 times before they die. (Exceptions are cancer cells, which have unlimited growth, and brain and muscle cells, which do not divide after birth). This suggests a genetic clock that limits how many time cells can divide. It is thought that as cell division decreases, as it does in older people, the functioning of the body also begins to slow down, resulting in aging and eventual death.

The wear-and-tear theory of aging and death suggests that genes (the molecules that carry instructions for passing on specific traits from one generation to another) are altered by random mutations (changes in form) that accumulate over time, gradually leading to aging and disease. Environmental agents, such as X rays, ultraviolet radiation, and chemical toxins, can contribute to this mutation process. All cells have the ability to repair damaged DNA (deoxyribonucleic acid, the molecular basis of heredity), but when these repair mechanisms fail, mutations can accu-

Words to Know

DNA (deoxyribonucleic acid): A compound composed of sugar, base, and phosphate groups and located in the nucleus of cells where hereditary information is stored.

Gene: A section of a DNA molecule that carries instructions for the formation, functioning, and transmission of specific traits from one generation to another.

Gerontology: The scientific study of aging with regard to its physical, social, economic, and psychological aspects.

Hormone: A chemical produced in living cells that is carried by the blood to organs and tissues in distant parts of the body, where it regulates cellular activity.

Life expectancy: The average age of death of an individual within a population.

Life span: The average maximum length of life for members of a species.

Menopause: Period in a woman's life when menstruation stops and childbearing is no longer possible, usually occurring between the ages of 45 and 50.

Proteins: Large molecules that are essential to the structure and functioning of all living cells.

mulate. This failure is also thought to be a factor in the development of cancer.

Two other factors are thought to contribute to aging: (1) protein damage from cross linkages and (2) the presence of free radicals in the body. Cross linkages are faulty bonds that can form in proteins, such as collagen. Collagen is a major component of connective tissue, which provides support to organs and elasticity to blood vessels. Cross-linkage in collagen molecules changes the shape and function of an organ's collagen supports and decreases vessel elasticity. Free radicals are normal chemical byproducts resulting from the body's use of oxygen. However, the buildup of free radicals, often the result of environmental abuses, can alter cellular function, causing damage. Antioxidants, such as vitamins C and E, block the action of free radicals and are therefore thought to retard aging.

Diseases associated with aging

Diseases associated with aging include cancer, cardiovascular (or heart) disease, diabetes mellitus, Alzheimer's, and Parkinson's. Diabetes is usually characterized by decreased production of insulin. (Insulin is a hormone essential to the metabolism of carbohydrates, sugars, and starches.) Alzheimer's is a degenerative disease of the brain cells that causes progressive loss of memory and concentration, as well as impaired learning and judgment. It primarily affects people over 65 years of age. As a larger proportion of Americans become elderly in the near future, scientists predict that the number of Alzheimer's cases will continue to rise. By 2050, it is estimated that 14 million Americans will have Alzheimer's disease. Parkinson's is a crippling disease in which the muscles become increasingly rigid, movement—such as walking—is difficult, and involuntary tremors (shakiness) develop.

Death

Death is marked by the end of blood circulation, the end of oxygen transport to organs and tissues, the end of brain function, and overall organ failure. The diagnosis of death can occur legally when breathing and heartbeat have stopped and when the pupils are unresponsive to light. Although Alzheimer's disease and AIDS (acquired immunodeficiency syndrome) receive much attention in the press, the two major causes of death in the United States are heart disease and cancer.

Other causes of death include stroke, accidents, infectious diseases, murder, suicide, and euthanasia (ending a hopelessly sick person's life for reasons of mercy). Loss of life can also result from genetic diseases, bacterial and viral infections, drug use, and alcoholism.

Agriculture

The development of agriculture—the raising of crops and animals for food—has been fundamental to the development of civilization. Farming brought about the settlement of farm communities, which grew into towns and city-states. Farming also made possible sedentary (settled) lifestyles, which in turn led to increased technological development. As growing populations demand an ever-increasing food supply, the need for agricultural advances continues to this day.

Four stages of agricultural development

Agriculture advanced in four major stages that were closely linked with other key historical periods. The first, the Neolithic or New Stone

Age, marks the beginning of sedentary farming. Although much of this history is lost in antiquity, dating back 10,000 years or more, anthropologists believe farming arose because of increasing population. The major technological development of this ancient time was the plow. Appearing in Mesopotamia (an ancient region in southwest Asia) around 4000 B.C., the plow allowed farmers to plant crops in rows, saving time and increasing food production.

The second major advance came as a result of Spanish explorer Christopher Columbus's voyages to the New World in the late fifteenth century. The connecting of the New World and the Old World saw the exchange of farming products and methods. From the New World came maize (Indian corn), beans, the "Irish" potato, squash, peanuts, tomatoes, and tobacco. From the Old World came wheat, rice, coffee, cattle, horses, sheep, and goats. Several Native American tribes adopted new lifestyles, notably the Navajo as sheepherders and the Cheyenne as nomads (wanderers) who used the horse to hunt buffalo. In the twentieth century, maize is a staple food in Africa.

The Industrial Revolution of the eighteenth and nineteenth centuries both contributed to and was supported by agriculture. The greatest agricultural advances came in transportation, where canals, railroads, and then steamships made possible the shipment of food. This in turn increased

Horses drawing a Holt combine harvester through wheat fields in Walla Walla, Washington, at the turn of the twentieth century.

productivity, but most important, it reduced the threat of starvation. Without these massive increases in food shipments, the exploding populations could not have been fed and the greatly increased demand for labor by emerging industries could not have been met.

As a consequence, the Industrial Revolution introduced major advances in farm technology, such as the cotton gin, mechanical reaper, threshing machine, mowing machine, improved plows, and, in the twentieth century, tractors and trucks. These advances enabled fewer and fewer farmers to feed larger and larger populations, freeing workers to fill demands for factory labor and the growing service industries.

Finally, scientific advances of the twentieth century—the refrigeration of meat, the development of hybrid crops, research into genetics—have greatly benefitted agriculture. Great potential exists for the development of crop and animal varieties with greatly improved dietary characteristics, such as higher protein or reduced fat.

Drawbacks to the rise of agriculture

The agricultural revolution is also associated with some of humankind's darker moments. In the tropical and subtropical climates of the

A nine-cutter no-till farming chisel plow on a present-day London, Ohio, farm. *(Reproduced by permission of Phototake.)*

New World, slave labor was used extensively in farm fields in the eighteenth and nineteenth centuries. In the late twentieth century, the mass production of animals, especially in close quarters, has been extremely controversial. While farmers view new breeding practices as useful means to producing more food, animal rights activists protest them as showing a disregard for animals' comfort and welfare. Additionally, the widespread use of fertilizers, pesticides, and other chemicals in agriculture have led to serious pollution crises in many areas of the world.

Famine throughout history shows mankind's desperate dependence on agriculture. Advances in farming, especially in the last few centuries, have led to increases in population. Growing populations—made possible by food surpluses—have forced agricultural expansion onto less and less desirable lands. Because agriculture drastically simplifies ecosystems (communities of plants and animals) and greatly increases soil erosion, many areas such as the Mediterranean basin and tropical forestlands have severely deteriorated.

The future of agriculture

Some argue that the agricultural revolution masks the growing hazards of an overpopulated, increasingly contaminated planet. In the nineteenth and twentieth centuries, agriculture more than compensated for the population explosion. Through scientific advances in areas such as genetic engineering, there is hope that the trend will continue. However, the environmental effects of the agricultural progress could soon undermine any advances if they are not taken seriously.

[*See also* **Agrochemical; Crops; Organic farming; Slash-and-burn agriculture**]

Agrochemical

An agrochemical is any substance used to help manage an agricultural ecosystem, or the community of organisms in a farming area. Agrochemicals include: (1) fertilizers, (2) liming and acidifying agents, (3) soil conditioners, (4) pesticides, and (5) chemicals used in animal husbandry, such as antibiotics and hormones.

The use of agrochemicals has been critical to the raising crops for food. However, some of these chemicals cause substantial environmental and ecological damage, greatly reducing their benefits.

Words to Know

Fertilizers: Any substance added to agricultural lands to encourage plant growth and higher crop production.

Hormone: A chemical produced in living cells that is carried by the blood to organs and tissues in distant parts of the body, where it regulates cellular activity.

Liming and acidifying agents: Substances added to soil to bring it into balance if it is too acidic or alkaline (basic).

Pesticides: Substances used to reduce the abundance of pests, any living thing that causes injury or disease to crops.

Fertilizers

Fertilizers are substances that are added to farmlands to encourage plant growth and to increase crop yields. Fertilizers may be chemically manufactured (synthetic) or be made from organic (living) material such as recycled waste, animal manure, or compost (decaying vegetation). Most fertilizers contain varying amounts of nitrogen, phosphorus, and potassium, which are inorganic (nonliving) nutrients that plants need to grow. Globally, about 152 million tons (138 million metric tons) of fertilizers are used each year. In the United States, the yearly total is about 21 million tons (19 million metric tons).

Liming and acidifying agents

Crops planted in soil that is either too acidic or too alkaline (basic) cannot obtain the proper nutrients they need to grow from that soil. Acidic soils, an especially common problem in agriculture, can be caused by various factors, including acid rain (precipitation that contains weak sulfuric and nitric acids) and the use of certain types of fertilizers. Acidic soils are commonly neutralized by adding compounds that contain calcium, usually in the form of powdered limestone or crushed oyster or mussel shells.

Much less common are alkaline soils, caused by the presence of large amounts of limestone or calcium. Alkaline soils can be brought into balance by adding sulfur compounds or certain types of acidic organic matter, such as peat (rotted vegetable matter found in bogs).

Soil conditioners

Soil conditioners are materials that are added to soil, usually to increase its ability to hold water and oxygen. Materials used as soil conditioners include peat, livestock manure, sewage sludge, and even shredded newspapers. Compost is probably the best soil conditioner because it keeps soil from becoming too acidic or too alkaline and it supplies the soil with organic nutrients.

Pesticides

Pesticides are used to eliminate the presence of pests, any living thing that causes injury or disease to crops. Although many kinds of pesticides are used in agriculture, they can be categorized into simple groups according to the pest they are targeting. Herbicides are used to kill weeds, any non-desired plant that interferes with the growth of crops. Fungicides are used to protect agricultural plants from fungal diseases. Insecticides are used to kill insects that eat crops or stored grains. Other pesticides target snails, slugs, mites, rodents, and birds.

Very large quantities of pesticides are used in modern agriculture. Globally, about 4.4 to 6.6 billion pounds (2 to 3 billion kilograms) of

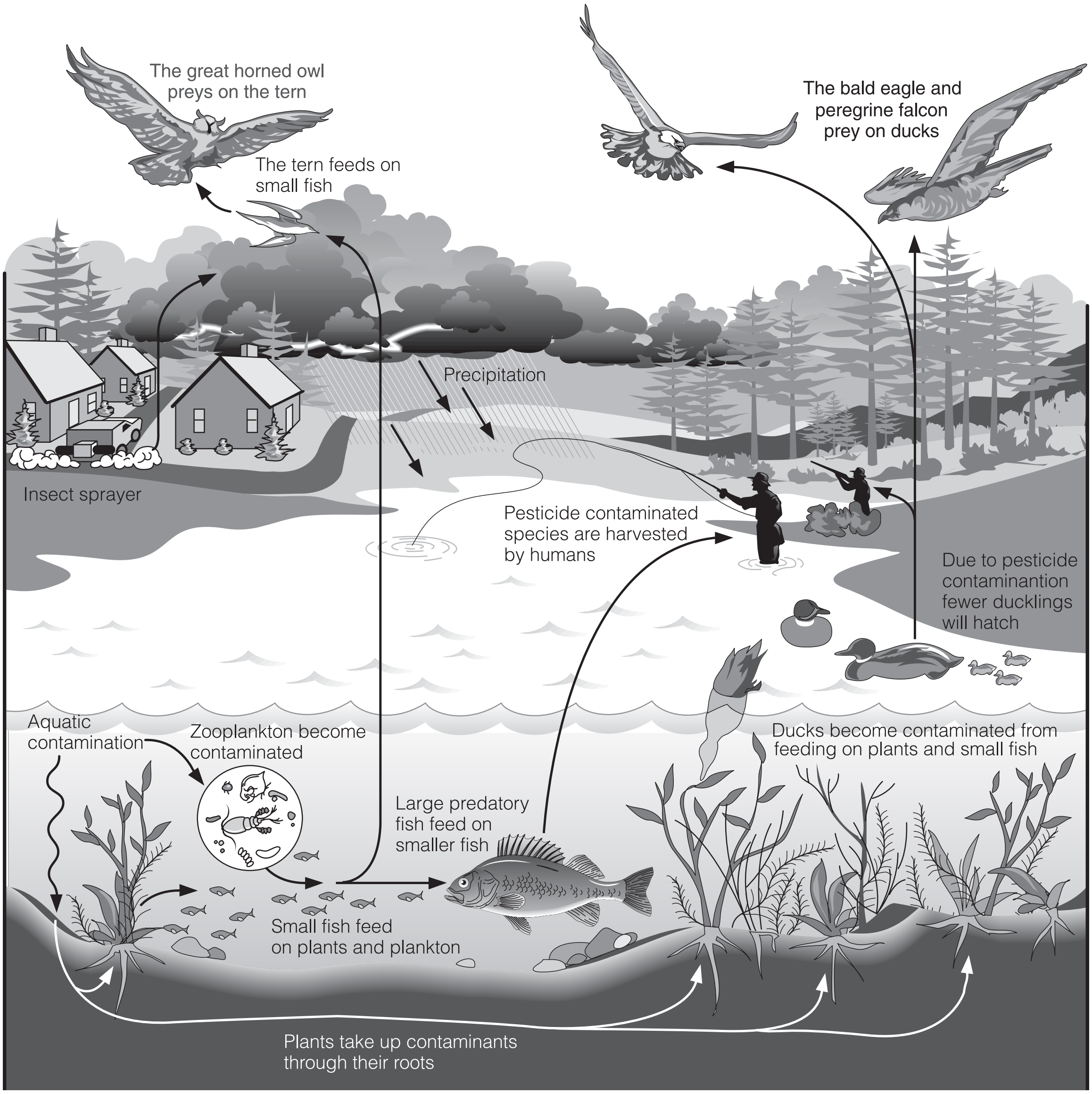
An orchard sprayer killing pests in fruit trees. *(Reproduced by permission of Phototake.)*

pesticides are used each year, at a total cost of about $20 billion. The United States alone accounts for about one-third of all pesticide usage.

Agrochemicals used for animal husbandry

Various agrochemicals are given to livestock. Antibiotics are administered, either by injection or combined with feed, to control infec-

The path of pesticides through the environment. *(Reproduced by permission of The Gale Group.)*



tious diseases and parasites that often arise when animals are raised under extremely crowded conditions. Hormones are routinely administered to increase the growth and productivity of animals, such as the bovine growth hormone given to cows.

Environmental effects of the use of agrochemicals

While agrochemicals increase plant and animal crop production, they can also damage the environment. Excessive use of fertilizers has led to the contamination of groundwater with nitrate, a chemical compound that in large concentrations is poisonous to humans and animals. In addition, the runoff of fertilizers into streams, lakes, and other surface waters can increase the growth of algae, leading to the death of fish and other aquatic animals.

Pesticides that are sprayed on entire fields using equipment mounted on tractors, airplanes, or helicopters often drift away from the targeted field, settling on nearby plants and animals. Some older pesticides, like the powerful insecticide DDT (dichlorodiphenyltrichloroethane), remain active in the environment for many years, contaminating virtually all wildlife, well water, food, and even humans with whom it comes in contact. Although many of these pesticides have been banned, some newer pesticides still cause severe damage. In North America, for example, it is believed that millions of wild birds are killed each year from exposure to the agricultural insecticide carbofuran.

These and other environmental effects have prompted researchers to search for nonchemical methods of enhancing soil fertility and dealing with pests. These alternatives, however, are still quite expensive at the beginning of the twenty-first century and are not yet in widespread use. In late 2000, the United Nations Environment Program organized a meeting to draft a global treaty to restrict the production and use of twelve persistent organic pollutants (POPs), especially those used as pesticides. The twelve toxic chemicals cited, which environmentalists have called the “dirty dozen,” include eight pesticides: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex, and toxaphene. Since it is still widely used in Africa to control malaria, DDT was given a special exemption. It can be used in those countries until replacement chemicals or strategies can be put into place. One hundred and twenty-two nations (including the United States) agreed to the treaty, but before it can take effect, at least fifty of those nations must also ratify it.

AIDS (acquired immunodeficiency syndrome)

Acquired immunodeficiency syndrome (AIDS) is a disease caused by the human immunodeficiency virus (HIV). HIV damages the immune system by attacking certain white blood cells called lymphocytes (specifically those called helper T cells). Lymphocytes normally help to protect the body against invading microorganisms. When these cells are destroyed, the body loses its ability to fight infection and becomes vulnerable to a variety of infections and rare cancers that are the hallmarks of AIDS.

From 1981 (when cases of AIDS were first recorded) through 2000, more than 753,000 cases of AIDS had been reported in the United States, resulting in over 360,000 deaths, 5,086 of which were children under the age of 15. It is the leading cause of death for people between the ages of 25 and 44. The World Health Organization estimated that at the beginning of the twenty-first century, 36.1 million adults and children around the world were living with AIDS or the virus. An estimated 21.8 million people have died from AIDS since the epidemic began. In 2000 alone, AIDS caused the deaths of an estimated 3 million people, including 1.3 million women and 500,000 children under 15. Eighty percent of those deaths occurred in Africa. Cases in Eastern Europe and Russia almost doubled in 2000. No cure has yet been found for the disease, and no vaccine is presently available to prevent it.

History and spread of AIDS

In the late 1970s, a rare form of cancer called Kaposi's sarcoma and an unusual type of pneumonia called *Pneumocystis carinii* began to appear in previously healthy homosexual and bisexual men in the United States. It was found that the patient's immune systems were not functioning properly, causing them to be susceptible to diseases that would not normally occur in a healthy person. Named AIDS in 1981, this destruction of the immune system also began to be seen among intravenous drug users, persons who had received blood transfusions, and sexual partners of people with the disease. It was determined that AIDS was caused by a virus that could be passed from person to person through contact with blood or bodily fluids. In 1983, the virus believed to cause AIDS was discovered and named HTLV-III (human T-cell lymphotropicvirus type III). It's name was soon changed to human immunodeficiency virus, or HIV.

Words to Know

Full-blown AIDS: The stage of HIV infection in which the immune system is so damaged that it can no longer fight off disease.

Helper T cell: A type of lymphocyte that is involved in the immune response and that is the primary target for the AIDS virus.

Immune system: The body's natural defense system that guards against foreign invaders and that includes lymphocytes and antibodies.

Intravenous drug: A drug injected into a vein of the body with a needle.

Kaposi's sarcoma: A rare cancer that forms purplish patches on the skin and mucous membranes in various parts of the body.

Lymphocyte: A type of white blood cell that is involved in the body's immune response.

Pneumocystis carinii: A pneumonia caused by a parasite and seen especially in persons whose immune systems are damaged.

Vaccine: A substance made from a killed or weakened live virus that is given to a person to provide them with immunity to a particular disease.

In early 2000, scientists at the Los Alamos National Lab in New Mexico traced the origin of the AIDS epidemic to one or a small group of humans around 1930. Previously, scientists had believed the epidemic arose around the 1950s. Experts now believe that the original virus normally infected chimpanzees. Somehow it spread to people, perhaps through a bite or a hunting mishap, in west equatorial Africa. Just when and how this happened still mystifies scientists.

How HIV damages the immune system

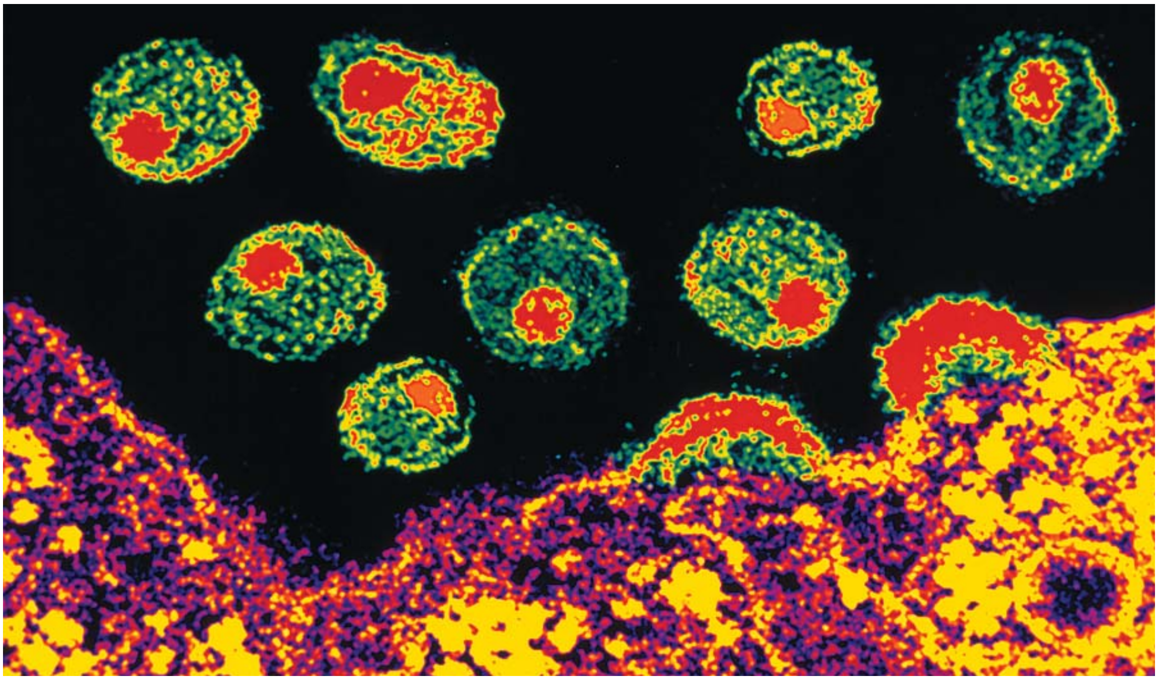
HIV damages the immune system by invading infection-fighting lymphocytes called helper T cells and eventually killing them. HIV enters helper T cells, then replicates (makes exact copies of itself) and produces new virus particles that are released into the bloodstream to attack other cells. A person infected with HIV may have no symptoms for 10 years or more before progressing to AIDS. In fact, by the late 1990s, some

people who had been diagnosed as HIV-positive seemed to have been able to "beat" the virus before it turned into full-blown AIDS. After treatment with a combination of drugs—known informally as cocktails—the levels of HIV in their blood decreased dramatically or even disappeared. (It is still unclear how these patients will fare over the long run.) Once a person is diagnosed with full-blown AIDS, however, survival rates drop sharply; death often occurs within five years.

Methods of transmission

AIDS can be transmitted through semen or vaginal fluids during unprotected sex with an infected person and through direct contact with infected blood. Intravenous drug users who share hypodermic needles are at an especially high risk. The AIDS virus can also be passed from an infected mother to her unborn child. Since screening measures began in 1985, transmission of the disease through transfusions of donated blood or blood products is now rare.

Scientists do not believe AIDS can be transmitted through saliva. There are enzymes in saliva that can break down the virus, and the pH (measure of the acidity of a solution) of the mouth is detrimental to the survival of the virus.



Mature HIV viruses (above) and the lymphocyte from which they emerged (below). Two immature viruses can be seen budding on the surface of the lymphocyte (right of center). *(Reproduced by permission of Photo Researchers, Inc.)*

Stopping the spread of AIDS

Efforts by health officials to stop the spread of AIDS have included urging couples to use condoms when engaging in sexual intercourse and promoting sex education. In addition, certain communities have instituted needle-exchange programs, in which intravenous drug users can turn in used hypodermic needles for new sterile ones.

HIV does not survive well outside the human body. It can be easily killed or deactivated by using heat, hand soap, hydrogen peroxide, or any solution containing 25 percent alcohol, bleach, Lysol, or other disinfectants.

AIDS therapies, vaccines, and a new treatment approach

There is presently no cure for AIDS. However, new therapies involving a combination of old drugs such as AZT and new drugs called protease inhibitors (the aforementioned cocktails) have shown some success in preventing HIV from reproducing itself once infection has taken place. This has the effect of reducing the amount of the virus present in the blood and seems to postpone the onset of full-blown AIDS in patients with early HIV infection. For those who already suffer from AIDS, the new therapies may help extend the lives of some patients. Research into developing an effective vaccine to prevent AIDS is ongoing, including the testing of several experimental AIDS vaccines. A new class of drugs, called entry inhibitors, works to block HIV before it even enters the cells of an infected person. These drugs may be made available to patients as early as 2002 or 2003. At the beginning of 2001, 18 anti-retroviral agents were available for prescription, either alone or in combination.

In early February 2001, federal health officials called for a new approach to treating people infected with the AIDS virus. Since the development of protease inhibitors and so-called drug cocktails in the mid-1990s, physicians have been quick to treat people infected with the virus, even if they were otherwise healthy. This "hit early, hit hard" approach was undertaken with hopes that, in a short time, the drugs might eliminate HIV from the body of an infected person.

However, research at the beginning of the twenty-first century showed that the drug cocktails do not cure HIV; once a person stops taking the drugs, the virus rebounds. This means that the person will have to continue taking the drugs throughout his or her life. In addition, researchers found that people undergoing the drug therapy suffered a higher

risk of nerve damage, weakened bones, diabetes, high levels of cholesterol, and other serious side effects.

To limit these toxic side effects, health officials urged that treatment using the drug cocktails be delayed for as long as possible for people who had HIV but did not show outward symptoms. The officials believed that in early treatment, the side effects tipped the balance between benefitting infected individuals and making their health worse.

[*See also* **Immune system; Protease inhibitors; Virus**]

Aircraft

An aircraft is a machine used for traveling through the atmosphere. There are two types of aircraft: the first type are known as lighter-than-air crafts, which are supported by their own buoyancy or ability to float. The second are known as heavier-than-air crafts, which require the use of some sort of engine to propel them through the air.

Early theories of air travel

Humans have dreamed of flying like birds for centuries. A Chinese myth dating to at least 1500 B.C. tells of men flying through the air in a carriage driven by something very much like a modern propeller. The Greek legend of Daedalus and Icarus is closer to the image that early humans had of flight, however. According to that myth, Daedalus constructed a set of wings that he attached to his son, Icarus, as a means of escaping from the island of Crete. Icarus flew so high, however, that the wax holding the wings to his body melted, and he fell to his death.

For more than 20 centuries, humans repeated Daedalus' experiment, with ever more sophisticated attempts to duplicate the flight of birds. All such attempts failed, however, as inventors failed to recognize that the power generated by a single human could never be sufficient to lift a person off Earth's surface.

Lighter-than-air craft

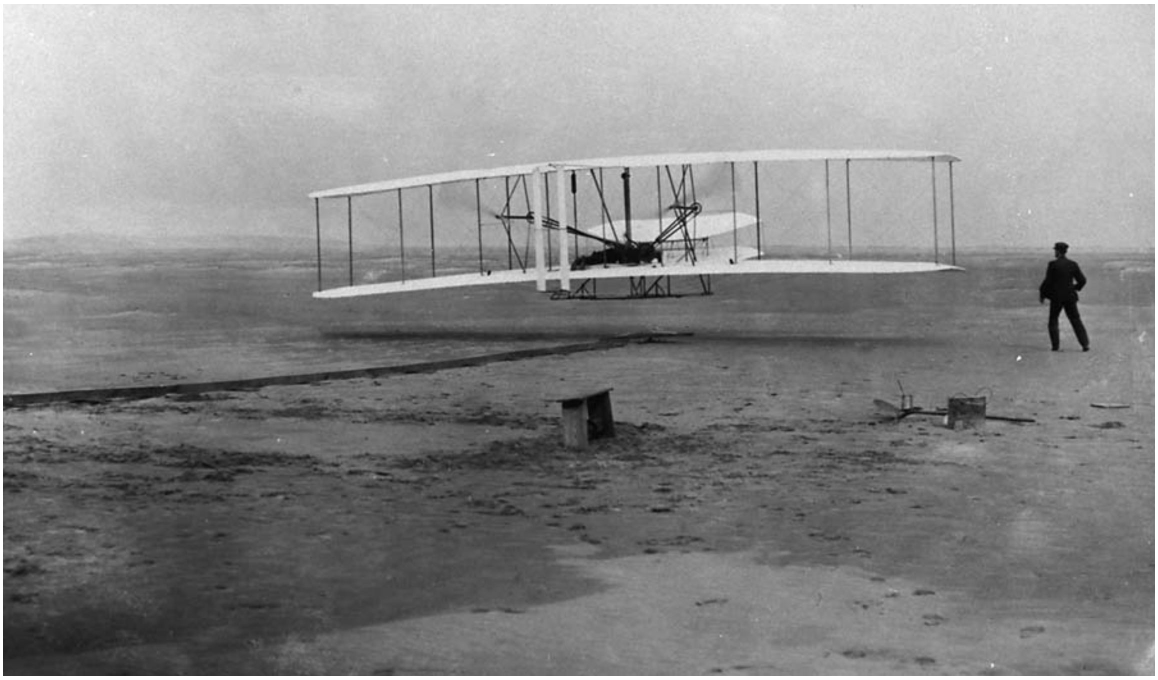
Successful flight was not possible until humans understood and made use of the concept of buoyancy. Buoyancy refers to the ability of an object to float or rise in a medium (such as water or air) because the ob-

ject's density is less than that of the medium. A cork floats in water, for example, because the cork is less dense than the water. Buoyant aircraft became possible when scientists discovered that certain gases—especially hydrogen and helium—are less dense than air. Heated air is also less dense than cooler air. Thus, a container filled with hydrogen, helium, or heated air will rise in normal air.

Balloons were the first aircraft to make use of this principle. The fathers of ballooning are sometimes said to be the Montgolfier brothers, Joseph and Jacques. In 1783, after a series of experiments, the brothers constructed a balloon large enough to carry two humans into the atmosphere, the first manned aircraft.

Balloons, however, are dependent on the wind for speed and direction. In the nineteenth century, cigar-shaped balloons were designed with propellers driven by steam engines to give greater control. These modified balloons came to be known as airships. The father of the modern rigid airship, known as a dirigible, is generally said to be German count Ferdinand von Zeppelin. Zeppelin's hydrogen-filled dirigible had a rigid aluminum frame over which a cloth skin was stretched. Able to be steered with complete control, Zeppelin-styled dirigibles transported more than 10,000 passengers by 1914.

Orville Wright is at the controls as brother Wilbur looks on during the Wrights' first successful flight, on December 17, 1903, at Kitty Hawk, North Carolina. *(Reproduced courtesy of the Library of Congress.)*



Words to Know

Airship: Cigar-shaped balloon that uses a steering and propulsion system.

Blimp: Airship without a rigid framework that often uses helium gas as its lifting agent.

Dirigible: Airship that has a rigid frame covered with fabric and uses hydrogen or helium gas as its lifting agent.

Drag: A force of resistance caused by the movement of an aircraft through the air, such as the friction that develops between air and the aircraft body.

Glider: A motorless aircraft, also known as a sailplane, that remains in the air by riding on rising currents of air.

Jet engine: An engine that obtains its power from burning a fuel within the engine, creating a backward thrust of gases that simultaneously pushes the engine forward.

Lift: Upper force on the wings of an aircraft created by differences in air pressure on top of and underneath the wings.

Pitch: Tendency of an aircraft to rotate in a forward or backward direction, tail-over-nose, or vice versa.

Roll: Tendency of an aircraft to twist vertically around its body, the right wing sliding upward and the left wing downward, or vice versa.

Thrust: Forward force on an aircraft provided by the aircraft's power system.

Yaw: Tendency of an aircraft to rotate in a horizontal motion, with the left wing forward and the right wing backward, or vice versa.

Dirigibles filled with highly flammable hydrogen gas presented one terrifying possibility: they might explode. This fear was realized in 1937 when the dirigible *Hindenburg* exploded while attempting to moor in New Jersey, killing 36 people. Although later dirigibles were designed to fly with nonflammable helium, they never really regained popularity. Today, nonrigid airships using helium gas, known as blimps, are widely used for advertising and television purposes. The Goodyear blimp and its cousins

have now become familiar sights at outdoor sporting events all over the United States.

Heavier-than-air craft

The father of heavier-than-air craft is said to be English scientist George Cayley (1773–1857). Cayley's research into flight laid the foundations of the modern science of aerodynamics, the study of the forces experienced by an object flying through the air. In 1853, he constructed his first working aircraft, a glider.

Gliders. A glider—also known as a sailplane—differs from a modern airplane only in that it has no power source of its own. Instead, it uses natural air movements such as updrafts and winds for propulsion and maneuvering. Gliders have very large wings, are made of the lightest possible material, and have extremely smooth surfaces. Any protrusion on the surface can produce friction that interferes with successful maneuvering. Properly designed gliders can remain in the air for hours and can travel at speeds of up to 150 miles per hour (240 kilometers per hour) using only natural updrafts.

Four fundamental aerodynamic forces

Modern aviation is said to have begun on December 17, 1903, at Kitty Hawk, North Carolina. Wilbur and Orville Wright, two bicycle makers from Dayton, Ohio, flew the world's first manned, powered, heavier-than-air craft. The steerable biplane (double-winged aircraft), with a gasoline engine and two propellers, remained in the air a total of only 12 seconds and covered only 120 feet (37 meters).

The problems that the Wright brothers had to solve in the early 1900s were essentially the same as those confronting aeronautical engineers in the late 1900s. In order to make a heavier-than-air machine fly, four factors have to be taken into consideration: weight, lift, thrust, and drag.

Weight and lift. Weight is caused by the pull of Earth's gravity on the airplane. To counteract this force, the plane must have a means of lift, or a force equal and opposite in direction to the pull of gravity. Aeronautical engineers know that the more quickly air moves over a surface, the less pressure it exerts on that surface. This is why the top and bottom surface of airplane wings are not identical. The top surface of a wing is designed to have a slightly curved shape, like half of a tear drop. The bottom surface of the same wing has a perfectly flat shape.

When air passes over a wing of this design, it moves faster and exerts less pressure on the top of the wing than it does on the bottom. Since the pressure under the wing is greater than the pressure on top of the wing, air tends to push upward on the wing, raising the airplane off the ground. Wing size and air speed combine to play a factor in this lift. The larger the wing, the greater the total force exerted on the bottom of the wing, giving greater lift. And the faster the air moves over a wing, the less pressure it exerts on top, also giving greater lift.

Thrust and drag. In addition to strong winds blowing over its wings, an airplane needs a forward thrust in order to move forward at a high rate of speed. The forward thrust for the aircraft comes from one of two sources: a rotating propeller blade powered by some kind of engine or a rocket engine.

The forward thrust provided by a propeller can be explained in exactly the same way as the lift on a wing. The propeller is shaped like a wing, with a rounded forward surface and a flat back surface. As the propeller rotates, air passes over its forward surface faster than it does over its back surface. As a result, the pressure on the forward surface is less than it is on the back, and the propeller is driven forward, carrying the airplane along with it.

The B-2 Stealth Bomber. *(Reproduced by permission of Photo Researchers, Inc.)*

The term drag refers to any factor that tends to slow down the forward movement of an aircraft. The most obvious type of drag is friction drag, a retarding force that results simply from the movement of an airplane through air. As air travels over an airplane wing, it does not travel smoothly, but tends to break apart and form eddies and currents that cause a drag on the airplane. One of the great challenges facing aeronautical engineers is to design aircraft in which all forms of drag are reduced to a minimum.

Aircraft stability

In flight, an airplane is subject to three major types of movements that, in the extreme, might cause it to crash: pitch, yaw, and roll. Pitch occurs when the nose of an airplane unexpectedly moves up or down. The horizontal tail at the back of an airplane body helps to prevent pitching. Yaw occurs when one wing unexpectedly moves forward while the other moves backward. Yawing is prevented partly by means of the vertical tail at the back of the airplane. Roll occurs when one wing unexpectedly moves upward while the other moves downward. Roll is prevented partly by having the outer edges of the wings tipped upward.

Jet engines

Until the 1940s, the only system available for powering aircraft was the piston-driven propeller engine. At the very end of World War II (1939–45), German scientists produced an entirely new type of power system, the jet engine. The center of the engine contains the elements necessary for its operation. Compressed air is mixed with a flow of fuel and ignited in a combustion chamber. Heated gases are formed, which push out of the rear of the engine. As the gases leave the engine, they also turn a turbine that compresses incoming air to begin the process once again.

The principle on which the jet engine operates was first developed by English physicist and mathematician Isaac Newton in the seventeenth century. According to Newton's third law of motion, for every action there is an equal and opposite reaction. In the jet engine, the action is the surge of burned gases flowing out of the back of the engine. The reaction to that stream of hot gases is a forward push that moves the engine—and the wing and airplane to which it is attached—in a forward direction. Because the exiting gases turn a turbine as well as power the engine, a jet of this kind is also known as a turbojet.

[*See also* **Aerodynamics; Balloon; Buoyancy; Jet engine; Radar**]

Air masses and fronts

An air mass is a large body of air that, at any one height, has a relatively steady temperature and moisture content throughout. Air masses typically cover areas ranging from hundreds of thousands to millions of square miles. A front is the boundary at which two air masses of different temperature and moisture content meet. The role of air masses and fronts in the development of weather systems was first recognized by the Norwegian father and son team of Vilhelm and Jacob Bjerknes in the 1920s. These two phenomena are still studied intensively as predictors of future weather patterns.

Source regions

Air masses form when a body of air comes to rest over an area that has an unvarying topography, or consistent surface features. Deserts, plains, and oceans typically cover very wide areas with relatively few topographical variations. In such areas, called source regions, large masses of air can accumulate without being broken apart by mountains, land/water intersections, or other surface features. A stable atmosphere, in which high winds are absent, is also necessary for the formation of an air mass.

Classification. Air masses are classified according to a two-letter system. The first letter, written in lower case, indicates whether the air mass

Cold fronts are usually accompanied by cumulonimbus thunderstorm clouds. *(Reproduced by permission of National Center for Atmospheric Research.)*

Words to Know

Continental: Referring to very large land masses.

Humidity: The amount of moisture in the air.

Maritime: Referring to the oceans.

Topographical: Referring to the surface features of an area.

forms over land or sea and therefore suggests, the relative amount of moisture in the mass. The two designations are c for continental (land) air mass and m for maritime (water) air mass. A second letter, written in upper case, indicates the approximate latitude (and, therefore, temperature) of the region: A for arctic; P for polar; E for equatorial; T for tropical.

The two letters are then combined to designate both humidity and temperature of an air mass. An air mass that developed in a source region over a large body of tropical water would be labeled mT (water, warm). An air mass that developed in a source region over an arctic landmass would be labeled cA (land, cold).

Fronts

Air masses create weather as they are moved by winds around the globe. Fronts develop at the boundary where two air masses with different temperatures—and, usually, different humidities—come into contact with each other. The term front was suggested by the Bjerkneses because the collision of two air masses reminded them of a battlefront during a military operation.

Cold fronts. A cold front develops when a cold air mass moves into an area occupied by a warm air mass. Because cold air is heavier or more dense than warm air, the cold air mass moves under the warm air mass. Cold fronts are usually accompanied by a decrease in air pressure and the development of large cumulus and cumulonimbus clouds that bring rain showers and thunderstorms. Rainfall and winds are most severe along the boundary between the two air masses. Cold fronts are represented on weather maps by solid lines with solid triangles. The direction in which the triangles point shows the direction in which the cold front is moving.

Warm fronts. A warm front develops when a warm air mass approaches and then slides up and over a cold air mass. As the warm air mass comes into contact with the cold air mass, it is cooled and some of the moisture held within it condenses to form clouds. In most cases, the first clouds to appear are high cirrus clouds. Some time later, lower-level stratus and nimbostratus clouds form, usually bringing widespread rainfall. Warm fronts are designated on weather maps by solid lines with solid half circles. The direction in which the half circles point shows the direction in which the warm front is moving.

Occluded fronts. A more complex type of front is one in which a cold front overtakes a slower-moving warm front. When that happens, the cold air mass behind the cold front eventually catches up and comes into contact with the cold air mass underneath the warm front. The boundary between these two cold air masses is an occluded front. Clouds form along this boundary, usually resulting in steady and moderate rainfall. An occluded front is represented on a weather map by means of a solid line that contains alternating triangles and half circles on the same side of the line.

Stationary fronts. In some instances, the collision of two air masses results in a stand-off. Neither mass is strong enough to displace the other, and essentially no movement occurs. The boundary between the air masses in this case is known as a stationary front and is designated on a weather map by a solid line with triangles and half circles on opposite sides of the line. Stationary fronts are often accompanied by fair, clear weather, although some light precipitation may occur.

[*See also* **Atmosphere, composition and structure; Storm; Weather forecasting**]

Alchemy

Alchemy was an early system of thinking about nature that contributed to the development of the modern science of chemistry. It was popular in ancient China, Persia, and western Europe throughout antiquity and the Middle Ages (400–1450). A combination of philosophy, metallurgical arts (the science of metals), and magic, alchemy was based on a distinctive worldview—that an essential correspondence exists between the microcosm and the macrocosm (the smallest and largest parts of the universe). Its objectives were: (1) to find ways of accelerating the rates at which metals were thought to "grow" within Earth in their development toward perfection (gold) and (2) to accomplish a similar perfection in humans by achieving eternal life.

Words to Know

Elixir: In alchemy, a substance that is supposed to have the power to change base metals into gold or to bring about human immortality.

Macrocosm: The whole extent of the universe.

Microcosm: A small part of the whole universe, as, for example, an individual human life.

Philosopher's stone: A material thought by alchemists to have the power to bring about the transmutation of metals.

Transmutation: The conversion of one substance into another, as in the conversion of lead or iron into gold.

Origins

Scholars do not know when or where alchemy originated. However, historians agree that alchemistic ideas and practices flourished in the ancient world within several cultural traditions. Even the term alchemy has remained mysterious; scholars have identified *al* as an Arabic article and proposed various possible meanings for the word *chem,* but a clear explanation of the term is still lacking.

Alchemy in China

The earliest alchemical practices are believed to have arisen in China in the fourth century B.C. The main emphasis in Chinese alchemy, it seems, was not on transmutation—the changing of one metal into another—but on the search for human immortality. In their search for an elixir (special liquid) of immortality, court alchemists experimented with mercury, sulfur, and arsenic. They sometimes created poisonous potions; several emperors died after drinking them. Such spectacular failures eventually led to the disappearance of alchemy in China.

Arabic alchemy

Alchemy flourished in parts of Islam in the eighth and ninth centuries. Court scientists, encouraged by their rulers, began studying and translating Greek philosophical and scientific works to aid them in their

quest. The greatest practitioner of Arabic alchemy was ar-Razi (also known as Rhazes; c. 850–c. 925), who worked in Baghdad.

This dogged pursuit of a recipe for gold led Arabic alchemists to study and classify chemical elements and chemicals. Ar-Razi speculated about the possibility of using "strong waters," which were in reality corrosive salt solutions, as the critical ingredient for the creation of gold. Experimentation with salt solutions led to the discovery of mineral acids, but scholars are not sure if Arabic alchemy should be credited with this discovery.

Alchemy in the Western world

The history of Western alchemy probably begins in the Egyptian city of Alexandria. Among the most prominent Alexandrian alchemists was Zosimos of Panopolis, Egypt, who may have lived in the third or fourth century A.D. In accordance with older traditions, Zosimos believed that a magical ingredient was needed for the creation of gold. Greek alchemists called this ingredient *xerion,* which is Greek for "powder." This word came into Latin and modern European languages as elixir and later became known as the elusive philosopher's stone.

After the fall of the Western Roman empire in the fifth century, Greek science and philosophy—as well as alchemy—sank into oblivion. In was not until the eleventh century that scholars rediscovered Greek learning, translating Greek scientific and philosophical works into Latin. The pioneers of medieval science, such as Roger Bacon (c. 1219–c. 1292), viewed alchemy as a worthwhile intellectual pursuit, and alchemy continued to exert a powerful influence on intellectual life throughout the Middle Ages. However, as in ancient China, alchemists' continued failure to produce gold eventually provoked skepticism and led to its decline.

In the sixteenth century, alchemists turned to more practical matters, such as the use of alchemy to create medicines. The greatest practitioner of this type of alchemy was Swiss physician and alchemist Philippus Aureolus Paracelsus (1493–1541), who successfully used chemical drugs to treat disease. Although a believer in magic, astrology, and alchemy, Paracelsus was also an empirical scientist (one who relies on observation and experimental methods); he contributed significantly to the development of medicine.

While alchemy is often considered to be unscientific, some great scientists, including Isaac Newton (1643–1727), took the subject seriously enough to conduct alchemical experiments. In addition, alchemy is credited with laying the foundation for the study of chemistry. Not only did

alchemists systematize and classify the knowledge of elements and chemicals, they also made a number of important discoveries, including sal ammoniac (ammonium chloride, which is used in batteries), saltpeter (potassium nitrate, which is used in gunpowder and the manufacture of glass; or sodium nitrate, which is used in rocket propellants and explosives), alcohol, and mineral acids. In addition, they developed a number of laboratory techniques, including distillation (a method of purifying a liquid) and crystallization (solidifying substances into crystals).

[*See also* **Chemistry**]

Alcoholism

Alcoholism is a serious, chronic (can be curbed or regulated but cannot be cured), potentially fatal condition in which a person has an uncontrollable urge to drink alcoholic beverages. Alcoholism can be seen in both the rich and the poor, the young and the old, and males and females. It is estimated that 75 percent of alcoholics are male and 25 percent are female.

Biological, psychological, social, and cultural factors all seem to play a role in the development of alcoholism. Children with a biological parent who is an alcoholic are more likely to become alcoholics than are children who do not have an alcoholic parent. Peer pressure, the social acceptability of drinking, and a desire to escape from emotional stress and anxiety can all set the stage for a person's descent into alcohol addiction.

How alcohol affects the body

Alcohol is a depressant that acts as a numbing agent on the central nervous system. Some adults can drink alcohol-containing beverages in moderate amounts without experiencing significant side effects. The ability to tolerate alcohol differs from person to person. Alcohol affects women more easily because women lack a stomach enzyme present in men that breaks down some of the alcohol before it reaches the intestines. Thus, if a man and a woman both drink a glass of wine, more alcohol will enter the woman's bloodstream than the man's.

Alcohol affects every cell in the body, especially those of the liver, heart, and brain. Excessive use can lead to permanent brain damage, heart disease, and cirrhosis (hardening; destruction) of the liver. Alcohol provides calories but no nourishment to the body. It also robs the body of vitamins and minerals necessary to maintain proper cell function.

Words to Know

Alcohol withdrawal delirium: The set of physical and psychological symptoms that occur when alcohol intake is stopped suddenly following excessive use.

Cirrhosis: A chronic disease of the liver in which scar tissue replaces normal cells, impairing blood flow.

Detoxify: To remove a poison or toxin from the body.

Metabolism: The physical and chemical processes that produce and maintain a living organism, including the breakdown of substances to provide energy for the organism.

When alcohol is ingested, it is absorbed from the intestines directly into the bloodstream, where it is carried to all organs of the body. Most of the alcohol consumed is passed to the liver, which detoxifies the alcohol by first converting it to a chemical called acetaldehyde (pronounced a-suh-TAL-duh-hide). Acetaldehyde is then changed to acetic acid, which is converted to carbon dioxide and water or to fat, according to the body's energy needs. If alcohol is consumed faster than the liver can process it, a sufficient amount is carried by the blood to the brain, affecting mental functioning.

In alcoholics, the conversion of acetaldehyde to acetic acid is slow to occur because of impaired liver function from previous alcohol abuse. Acetaldehyde thus accumulates in other organs of the body, causing symptoms such as staggering gait, shaking hands, blinding headaches, and hallucinations. High levels of acetaldehyde can result in pain, which can be eased temporarily by further drinking.

The stages of alcoholism. In the first stage of alcoholism, a person may drink heavily and remain functional. Withdrawal symptoms are absent other than the standard hangover that follows excessive drinking. The body's cells adapt to large quantities of alcohol and use the energy it provides to continue functioning. However, alcohol eventually begins to attack cell structures, erode cell membranes, and alter cellular chemical balances. Fatty deposits accumulate in the liver cells, causing the "fatty liver" common in heavy drinkers.

No definite signpost marks the border between the early and middle stages of alcoholism, and the change may take years. Eventually, how-

Fetal Alcohol Syndrome

Fetal alcohol syndrome (FAS) is a group of birth defects found in some children whose mothers drank alcohol during pregnancy. Since a fetus or unborn baby receives its nourishment directly from the blood stream of its mother, alcohol easily enters the fetus's body. The level of alcohol in a fetus's blood is the same as that of its mother's within just a few short minutes after the mother has begun drinking.

The effects of FAS range from mild to severe, depending on the amount and frequency of alcohol consumed by a mother during her pregnancy. The weight and height of newborns suffering from FAS is lower than average. They also have physical disabilities such as low muscle tone, a smaller than normal skull, and irregularities of the face including small eye sockets. After infancy, children suffering from FAS display nervous system disorders such as hyperactivity, learning deficiencies, temper tantrums, short attention span, inability to concentrate, and seizures.

FAS results in more babies being born mentally retarded than any other known factor. Yet it is completely preventable if a pregnant mother stops drinking alcohol during her entire pregnancy.

ever, the alcoholic drinks to counteract the symptoms of alcoholism, not to get high or to be able to function better. Deterioration of cells in all parts of the body produce symptoms such as severe headaches, trembling, chills, and nausea when the level of alcohol in the blood falls.

As cellular metabolism becomes more and more dependent upon alcohol, an alcohol-dependent person shows signs of alcohol withdrawal delirium when intake is stopped abruptly. He may experience loss of appetite and uncontrollable bodily shaking, become frightened and shrink into a corner, or become dangerous as he lashes out to protect himself from an imaginary attack. The person may also manipulate his hands as if playing a game of cards, throwing dice, or whittling. These symptoms require immediate medical attention as they can be precursors to a heart attack, stroke, or respiratory failure.

In the final stage of alcoholism, the cellular demand for alcohol is so great that the alcoholic must drink constantly to avoid his painful symptoms. The heart, pancreas, digestive, respiratory, and nervous systems all show characteristic changes. The liver suffers the most extensive

damage. About 10 percent of persons in this stage die from liver failure as a result of cirrhosis, a disease in which scar tissue forms in the liver and affects its ability to function properly. Perhaps a third die from accidents such as falling down stairs or drowning, or by committing suicide.

Treatment

There is no cure for alcoholism. Treatment consists of total avoidance of alcohol. Therapeutic programs lasting about four weeks are recommended to support the patient through withdrawal, medically treat physical problems brought on by alcohol abuse, and educate the patient about his condition and the need to abstain from alcohol. Individual, group, and family therapy are also usually included in the recovery process. To discourage alcoholics from drinking, they are sometimes given medication that causes a severe, unpleasant reaction if mixed with alcohol.

Continued support through participation in a group such as Alcoholics Anonymous can help the alcoholic adjust to life without alcohol. Many will need this type of support for the rest of their lives. An alcoholic has about a 50 percent chance of successful recovery from addiction.

[*See also* **Addiction; Alcohols**]

Alcohols

Alcohols are organic (carbon-containing) compounds derived from hydrocarbons (organic compounds composed of only carbon and hydrogen). They are formed by replacing the hydrogen atoms in their parent hydrocarbons with one or more hydroxyl groups. Each hydroxyl group (–OH) is made up of one atom of oxygen and one atom of hydrogen and is referred to as a functional group. Functional groups generally determine how a molecule will behave. Alcohols with one hydroxyl group include methanol, ethanol, and propanol.

Names and properties

Alcohols are named from their parent hydrocarbon by substituting the suffix -ol for the final -e. For example, ethane becomes ethanol, methane becomes methanol, and propane becomes propanol.

The lower an alcohol's molecular weight (determined by the number of carbon atoms), the more soluble it is (or the easier it can be dis-

solved) in water. A greater number of hydroxyl groups (–OH) also increases water solubility because hydrogen bonds can form between the alcohol molecule and water. As the number of carbon atoms increases, hydrogen bonding is disturbed and solubility in water decreases. Hydrogen bonding is also a factor in the boiling points of alcohols. In this case, hydrogen bonds can form between hydrogen and oxygen atoms in adjacent molecules (molecules located next to each other). When alcohols are heated, the energy needed to break these bonds determines the boiling point. The more hydroxyl groups an alcohol molecule has, the higher its boiling point.

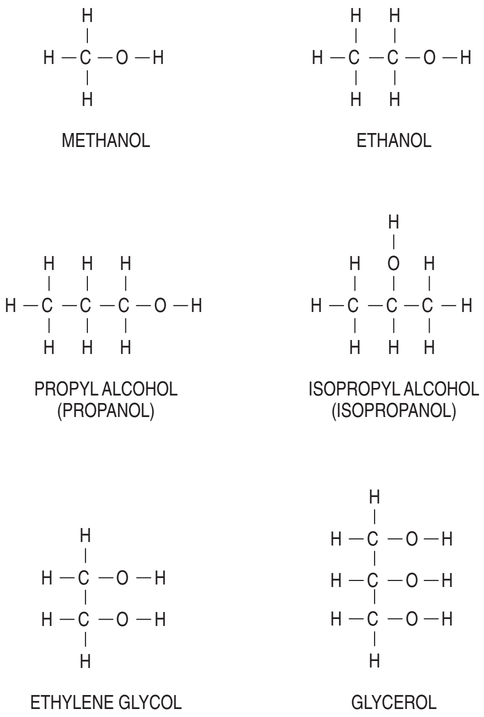
Alcohols and their uses

Methanol. Methanol (methyl alcohol) is the simplest of the alcohols. Also known as wood alcohol, it was originally produced by heating hardwoods to high temperatures without air (called destructive distillation). Today, methanol is produced from natural gas or synthetically from synthesis gas. Synthesis gas is a mixture of carbon monoxide, hydrogen, and methane obtained when heated, crushed coal is treated with superheated steam in a process called coal gasification.

Methanol occupies an important place in industry. It is used in the synthesis of organic chemicals such as formaldehyde (the basis for various polymers—compounds with repeating structural units), acetic acid, and methyl-t-butyl ether (MTBE, an additive that increases gasoline's oxygen content [the number used to measure the antiknock properties of a liquid motor fuel]). Methanol is also used as an antifreeze in windshield washer fluid. It can be utilized directly as a fuel to replace gasoline, but it evaporates quickly and its use requires major automobile engine modifications. This alcohol is extremely toxic and can cause poisoning and blindness if ingested.

Ethanol. Ethanol (ethyl alcohol) is best known as the active ingredient in alcoholic beverages. It is produced by the fermentation (or chemical changes) of sugars and starches in fruits and some plants, using techniques that were developed thousands of years ago. In fact, ancient Egyptian papyrus scrolls exist with directions for making beer from dates and other

The molecular structures of some alcohols:



Words to Know

Alcohol: Any of the large number of molecules containing a hydroxyl (-OH) group bonded to a carbon atom to which only other carbon atoms or hydrogen atoms are bonded.

Destructive distillation: An antiquated process of heating wood to high temperature in the absence of air to obtain small amounts of alcohols, particularly methanol.

Distillation: The process of separating liquids from solids or from other liquids with different boiling points by a method of evaporation and condensation, so that each component in a mixture can be collected separately in its pure form.

Fermentation: The action of microorganisms such as yeast on carbohydrates (sugars and starches), resulting in the conversion of sugar to alcohol and carbon dioxide.

Hydroxyl group: The -OH group attached to a carbon atom in a molecule and the site of most chemical reactions; also called the functional group.

Synthesis gas: A mixture of carbon monoxide and hydrogen gases obtainable both from coal and natural gas and used in the synthesis of alcohols and other organic compounds.

food plants. During fermentation, glucose and other sugars from fruits, vegetables, honey, or grains such as barley are converted into alcohol through the action of yeast. Ethanol is also known as grain alcohol or simply as alcohol. Both beer (usually made from barley and flavored with hops) and wine (made from grapes and many other fruits) are products of the fermentation process.

The alcoholic content of a substance can be increased by distillation following fermentation. Distillation is accomplished by heating the liquid until it evaporates, then collecting the resulting vapor and returning it to a liquid state. Distillation of alcohol for medicine was established by the early twelfth century in Italy, where herbs and spices were added to the distilled product. It is believed that this practice led to the development of liqueurs such as Benedictine and Chartreuse. Later, other organic mixtures were fermented and distilled—wine into brandy, grain into whiskey, sugar mash into rum, and vodka from potatoes. Ethanol is one of the least

toxic of the alcohols, but if enough is ingested in its pure form, poisoning and even death can occur.

Ethanol is also very important in industry. It is used in the synthesis of many organic chemicals and as a solvent in the preparation of essences, tinctures, varnishes, and food extracts such as vanilla. In addition, it is used as an ingredient in perfumes, dyes, and as a skin antiseptic. Ethanol is produced for industrial use by chemically adding water to ethylene, a process called high-pressure hydration.

Gasohol. Gasohol, a mixture of gasoline and up to 10 percent ethanol, has gained some acceptance as a fuel for automobiles. Adding ethanol to gasoline increases the oxygen content of the fuel, thus lowering carbon monoxide emissions from automobiles. It also raises the octane rating of the gasoline, causing smoother fuel performance. Gasohol is mainly produced using corn, which is fermented, and the fermentation products are then distilled to yield pure ethanol.

Propanol. Propanol can exist in two forms, 1-propanol (n-propyl alcohol) and 2-propanol (isopropyl alcohol), because the –OH group can be attached either at the end or in the middle of the carbon atom chain. Isopropyl alcohol is the main ingredient in rubbing alcohol, an effective disinfectant. It is also widely used in industry as a solvent for paints and chemical processes.

Ethylene glycol. Ethylene glycol, with two hydroxyl groups, is very water soluble and has a relatively high boiling point. Both these properties make it ideal for use as an antifreeze in automobiles.

Glycerol. Glycerol (or glycerin) is a nontoxic, clear, syrupy liquid made from fats and oils. With its three hydroxyl groups, glycerol bonds well with water and has good moisturizing properties. It is used as an ingredient in soaps, skin lotions, and even foods. Glycerol is also used as a lubricant and in the manufacture of explosives.

[*See also* **Distillation; Fermentation; Hydrogen**]

Algae

Algae (singular: alga) are plants or plantlike organisms that contain chlorophyll (pronounced KLOR-uh-fill) and other pigments (coloring matter) that trap light from the Sun. This light energy is then converted

Words to Know

Carbohydrate: A compound consisting of carbon, hydrogen, and oxygen found in plants and used as a food by humans and other animals.

Photosynthesis: Process by which light energy is captured from the Sun by pigment molecules in plants and algae and converted to food.

Phytoplankton: Microscopic algae that live suspended in the water.

Zooplankton: Tiny animals that drift through the upper surface of water bodies and feed on phytoplankton.

into food molecules in a process called photosynthesis. Most algae store energy as some form of carbohydrate (complex sugars).

Algae can be either single-celled or large, multicellular organisms. They can occur in freshwater or salt water (most seaweeds are algae) or on the surfaces of moist soil or rocks. The multicellular algae lack the true stems, leaves, or roots of the more complex, higher plants, although some—like the giant kelp—have tissues that may be organized into structures that serve particular functions. The cell walls of algae are generally made of cellulose and can also contain pectin, which gives algae its slimy feel.

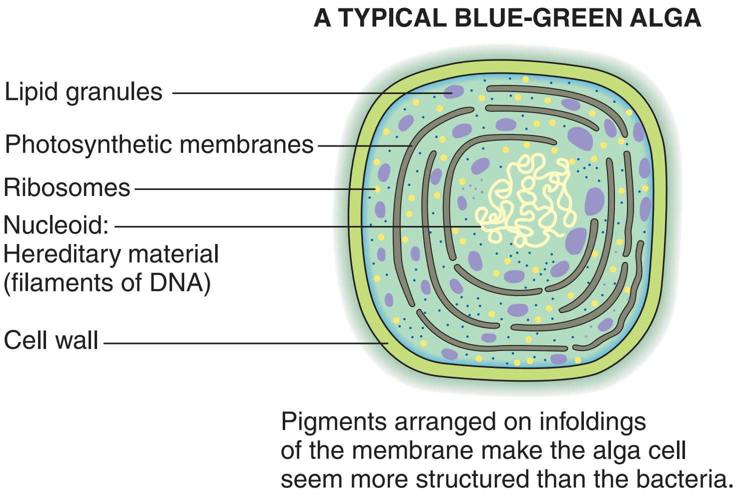
Types of algae

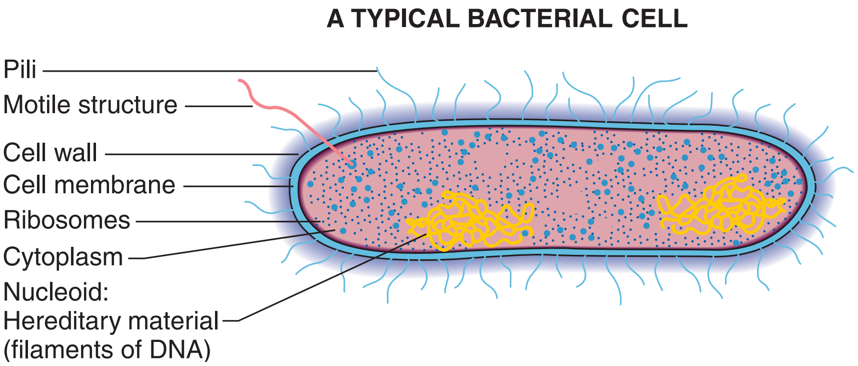
Although the term algae originally referred to aquatic plants, it is now broadly used to include a number of different groups of unrelated organisms. There are seven divisions of organisms that make up the algae. They are grouped according to the types of pigments they use for photosynthesis, the makeup of their cell walls, the types of carbohydrate compounds they store for energy, and the types of flagella (whiplike structures) they use for movement. The colors of the algae types are due to their particular mixtures of photosynthetic pigments, which typically include a combination of one or more of the green-colored chlorophylls as their primary pigments.

Euglenoids (Euglenophyta). The euglenoids, or Euglenophyta, are single-celled, protozoan-like algae, mostly occurring in freshwater. Unlike all other algae, they have no cell wall. Most euglenoids make their

own food using light energy from the Sun but are capable of surviving in the dark if fed organic materials. Some species are heterotrophic, meaning they do not produce their own food but feed on organic matter suspended in the water.

Golden-brown algae (Chrysophyta). The Chrysophyta, or golden-brown algae and diatoms, are named for the yellow pigments they possess. These single-celled algae live both in freshwater and salt water. Their cell walls have no cellulose but are composed mostly of pectin, which is often filled with silica, a compound that makes the walls quite rigid. These algae store energy both as a carbohydrate and as large oil droplets. Diatoms have two glass shells made largely of silica that fit together like a pillbox and are exquisitely marked. Their species number from 40,000 to 100,000. When they die, their shells help to form sediments on the sea





The difference between an alga cell and a bacterial cell. *(Reproduced by permission of The Gale Group.)*

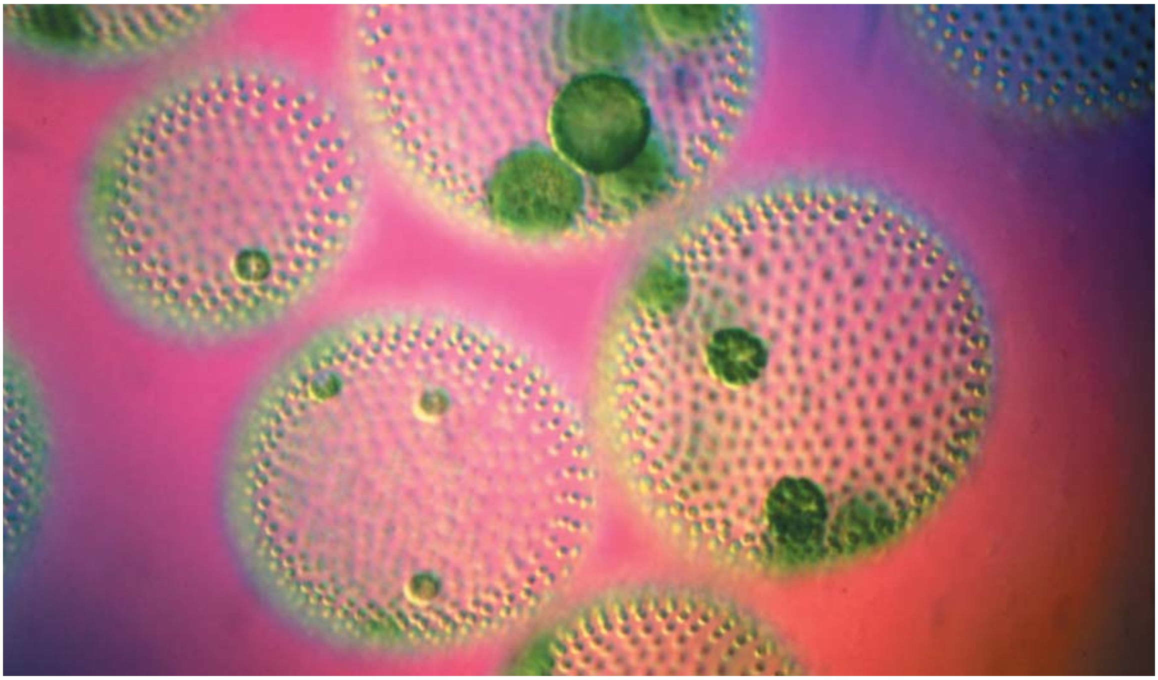
bottom. This fine-grained sediment is often used for filtration in liquid purification systems.

Fire algae (Pyrrophyta). Fire algae, or Pyrrophyta, are single-celled algae and include the dinoflagellates (pronounced dye-no-FLAJ-uh-lets), which have two flagella used for locomotion. Most of these microscopic species live in salt water, with some occurring in freshwater. Some species of dinoflagellates emit bright flashes of light when exposed to air, which at night look like fire on the ocean's surface.

Green algae (Chlorophyta). The green algae, or Chlorophyta, occur in freshwater, although some live in the sea. Most green algae are single-celled and microscopic (able to be seen only under a microscope), forming the slimy green scum found in stagnant ponds. Others are larger and more complex, forming spherical (round) colonies composed of many cells or occurring as straight or branched filaments (long, thin series of cells). Green algae are thought to be in the evolutionary line that gave rise to the first land plants.

Red algae (Rhodophyta). The red algae, or Rhodophyta, are marine plants that live mainly in shallow waters and deep tropical seas. A few also occur in freshwater. Their body forms range from single-celled to

Green algae magnified to 50 times its original size. *(Reproduced by permission of Custom Medical Stock Photo, Inc.)*



branched filaments. The larger species have filaments that are massed together and resemble the leaves and stems of plants. They have no flagella and typically grow attached to a hard surface or on other algae. Some species contain a red pigment; others range in color from green to red, purple, and greenish-black. The cell walls of Coralline red algae become heavily encrusted with minerals and help to cement and stabilize coral reefs.

Brown algae (Phaeophyta). The brown algae, or Phaeophyta, are shiny brown seaweeds that are especially abundant along rocky coasts, although some float in the open ocean. Brown algae are large in size and include the giant kelps, which are located along the Pacific coast and form forests that provide habitat to a wide range of marine life. Some species of brown algae have structures called holdfasts that anchor the algae to submerged rocks. Attached to the holdfasts are stemlike stalks that support wide leaflike blades. These blades provide the major surface for nutrient exchange and photosynthesis and are lifted up toward the water's surface by air bladders. Brown algae contain an accessory brown-colored pigment that gives the plants their characteristic dark color. Other well-known brown algae are the common rockweed *Fucus* and *Sargassum,* which floats in a thick, tangled mass through the Sargasso Sea—a huge area of slow currents in the mid-Atlantic Ocean that supports a variety of marine organisms.

Yellow-green algae (Xanthophyta). The yellow-green algae, or Xanthophyta, primarily occur in freshwater. They can be either single celled or form colonies, their cell walls are made of cellulose and pectin compounds that sometime contain silica, they can have two or more flagella for locomotion, and they store their energy as carbohydrates. They derive their yellow-green color from the pigments carotenoids and xanthrophyll.

Ecological importance of algae

Microscopic algae are the source of much of Earth's oxygen. Algae are also very important ecologically because they are the beginning of the food chain for other animals. Phytoplankton, a mostly single-celled type of algae, are eaten by small animals called zooplankton (mostly crustaceans such as tiny shrimp) that drift near the surface of the sea. The zooplankton are in turn fed upon by larger zooplankton, small fish, and some whales. Larger fish eat the smaller ones. At the top of the open-water food web may be fish-eating birds, seals, whales, very large fish such as sharks or bluefin tuna, and humans.

Algal Blooms

Algal blooms are an overabundance of algae that can severely affect the aquatic ecosystems in which they occur. Some marine species of dinoflagellates grow wildly at times, causing red tides that turn the surrounding sea a deep red color. The great numbers of microorganisms can rob the water of oxygen, causing many fish to suffocate.

The dinoflagellates also produce extremely poisonous chemicals that can kill a wide range of marine animals, as well as humans who eat shellfish containing the toxins. Red tides are natural events, although some scientists believe human interference contributes to their occurrence in certain regions.

Freshwater algae can also cause problems when they are overly abundant. Algal blooms can cause foul tastes in water stored in reservoirs that are used to provide drinking water to nearby communities.

Eutrophication is a major problem that is associated with algal blooms in lakes. A direct result of human interference, eutrophication is caused by the addition of excess nutrients (runoffs of phosphate and nitrate from chemical fertilizers and sewage disposal) to the water that encourage algae to grow abundantly. As the algae die and sink to the bottom, most of the water's oxygen is consumed in breaking down the decaying plant matter. Fish and other animals that require large amounts of oxygen can no longer survive and are replaced by organisms with lower oxygen demands.

The larger algae provide shelter and habitat for fish and other invertebrate animals. As these algae die, they are consumed by organisms called decomposers (mostly fungi and bacteria). The decomposers feed on decaying plants and release important minerals that are used by other organisms in the food web. In addition, the plant matter partially digested by the decomposers serves as food for worms, snails, and clams.

Economic products obtained from algae

Brown and red seaweeds provide important economic products in the form of food for people and resources in the manufacturing of industrial products. These seaweeds are mostly harvested from the wild, although efforts are being made to cultivate large algae.

A red alga known as *nori* is a popular food in Japan. Another alga known as sea kale is consumed dried or cooked into various stews or soups. Sea lettuce and edible kelp are other commonly eaten seaweeds.

Brown seaweeds provide a natural source for the manufacture of chemicals called alginates that are used as thickening agents and stabilizers in the industrial preparation of foods and pharmaceutical drugs. Agar is a seaweed product prepared from certain red algae that is used in the manufacturing of pharmaceuticals and cosmetics, as a culture medium for laboratory microorganisms, and in the preparation of jellied desserts and soups. Carrageenin is an agarlike compound obtained from red algae that is widely used as a stabilizer in paints, pharmaceuticals, and ice cream.

[*See also* **Food web and food chain**]

Algebra

Algebra is often referred to as a generalization of arithmetic: problems and operations are expressed in terms of variables as well as constants. A constant is some number that always has the same value, such as 3 or 14.89. A variable is a number that may have different values. In algebra, letters such as a, b, c, x, y, and z are often used to represent variables. In any given situation, a variable such as x may stand for one, two, or any number of values. For example, in the expression $x + 5 = 7$, the only value that x can have is 2. In the expression $x^2 = 4$, however, x can be either +2 or −2. And in the expression $x + y = 9$, x can have an unlimited number of values, depending on the value of y.

Origins of algebra

Algebra became popular as a way of expressing mathematical ideas in the early ninth century. Arab mathematician Al-Khwarizmi is credited with writing the first algebra book, *Al-jabr wa'l Muqabalah,* from which the English word algebra is derived. The title of the book translates as "restoring and balancing," which refers to the way in which equations are handled in algebra. Al-Khwarizmi's book was influential in its day and remained the most important text in algebra for many years.

Al-Khwarizmi did not use variables in the same way they are used today. He concentrated instead on developing procedures and rules for solving many types of problems in arithmetic. The use of letters to stand for variables was first suggested in the sixteenth century by French mathematician Françoise Vièta (1540–1603). Vièta appears to have been the

first person to recognize that a single letter (such as x) can be used to represent a set of numbers.

Elementary algebra

The rules of elementary algebra deal with the four familiar operations of addition, subtraction, multiplication, and division of real numbers. A real number can be thought of as any number that can be expressed as a point on a line. Constants and variables can be combined in various ways to produce algebraic expressions. Numbers such as $64x^2$, 7yt, s/2, and 32xyz are examples. Such numbers combined by multiplication and division only are monomials. The combination of two or more monomials is a polynomial. The expression $a + 2b - 3c + 4d + 5e - 7x$ is a polynomial because it consists of six monomials added to and subtracted from each other. A polynomial containing only two parts (two terms) is a binomial, and one containing three parts (three terms) is a trinomial. Examples of a binomial and trinomial, respectively, are $3x^2 + 2y^2$ and $4a + 2b^2 + 8c^3$.

One primary objective in algebra is to determine the conditions under which some statement is true. Such statements are usually made in the form of a comparison. One expression can be said to be greater than (>), less than (<), or equal to (=) a second expression. The purpose of an algebraic operation, then, is to find out precisely when such conditions are true.

For example, suppose the question is to find all values of x for which the expression $x + 3 = 12$ is true. Obviously, the only value of x for which this statement is true is $x = 9$. Suppose the problem, however, is to find all x for which $x + 3 > 12$. In this case, an unlimited possible number of answers exists. That is, x could be 10 (because $10 + 3 > 12$), or 11 (because $11 + 3 > 12$), or 12 (because $12 + 3 > 12$), and so on. The answer to this problem is said to be indeterminate because no single value of x will satisfy the conditions of the algebraic statement.

In most instances, equations are the tool by which problems can be solved. One begins with some given equality, such as the fact that $2x + 3 = 15$, and is then asked to find the value of the variable x. The rule for dealing with equations such as this one is that the same operation must always be performed on both sides of the equation. In this way, the equality between the two sides of the equation remains true.

In the above example, one could subtract the number 3 from both sides of the equation to give: $2x + 3 - 3 = 15 - 3$, or $2x = 12$. The condition given by the equation has not changed since the same opera-

tion (subtracting 3) was done to both sides. Next, both sides of the equation can be divided by the same number, 2, to give: 2x/2 = 12/2, or x = 6. Again, equality between the two sides is maintained by performing the same operation on both sides.

Applications. Algebra has applications at every level of human life, from the simplest day-to-day mathematical situations to the most complicated problems of space science. Suppose that you want to know the original price of a compact disc for which you paid $13.13, including a 5 percent sales tax. To solve this problem, you can let the letter x stand for the original price of the CD. Then you know that the price of the disc plus the 5 percent tax totaled $13.13.

That information can be expressed algebraically as x (the price of the CD) + 0.05x (the tax on the CD) = 13.13. In other words: x + 0.05x = 13.13. Next, it is possible to add both of the x terms on the left side of the equation: 1x + 0.05x = 1.05x. Then you can say that 1.05x = 13.13. Finally, to find the value of x, you can divide both sides of the equation by 1.05: 1.05x/1.05 = 13.13/1.05, or x = 12.50. The original price of the disc was $12.50.

Higher forms of algebra

Other forms of algebra have been developed to deal with more difficult and special kinds of problems. Matrix algebra, as an example, deals with sets of numbers that are arranged in rectangular boxes, known as matrices (the plural form of matrix). Two or more matrices can be added, subtracted, multiplied, or divided according to rules from matrix algebra. Abstract algebra is another form of algebra that constitutes a generalization of algebra, just as algebra itself is a generalization of arithmetic.

[*See also* **Arithmetic; Calculus; Complex numbers; Geometry; Topology**]

Alkali metals

The alkali metals are the elements that make up Group 1 of the periodic table: lithium, sodium, potassium, rubidium, cesium, and francium. These elements are all much too active to exist in nature in their native state. However, they do form a number of important compounds, such as table salt (sodium chloride), borax (sodium tetraborate), potash (potassium carbonate), and washing soda (sodium carbonate).

Because the alkali metals all have one electron in the outer orbit of their atoms, they have similar chemical and physical properties. All are shiny, soft enough to cut with a knife, and—with the exception of cesium—white. They all react with water vigorously to form hydrogen gas and the hydroxide of the metal. As an example, when potassium metal is added to water, it floats on top of the water and produces an extreme reaction. In fact, so much heat is released that the hydrogen gas produced in the reaction begins to burn.

The usual method for detecting compounds of the alkali metals is with a flame test. A platinum wire is dipped into a solution of the unknown compound and then placed into a hot flame. The color produced is characteristic of the alkali metal present. The lithium flame is bright red; sodium, yellow; potassium, violet; rubidium, dark red; and cesium, blue.

The compounds of lithium, sodium, and rubidium have a number of important practical applications, while the remaining alkali metals have only a limited number of uses.

Lithium

Lithium occurs in small amounts in Earth's surface, usually in association with compounds of aluminum. Most people know lithium best because of its use (in the form of lithium carbonate) as a way of controlling certain mental disorders. People who suffer from manic depression (a mental illness in which highly excited, agitated manic moods alternate with sad, depressed moods) can often benefit from regular treatments with lithium carbonate. Lithium is also used industrially in lubricants, batteries, glass, and alloys (mixtures of metals) with lead, aluminum, and magnesium.

Sodium

Sodium is the seventh most abundant element in Earth's surface. It occurs commonly in Earth's oceans in the form of sodium chloride and in crustal rocks as sodium chloride, sodium carbonate, sodium nitrate (saltpetre), sodium sulfate, and sodium borate (borax).

Compounds of sodium are among the most important in all of the chemical industry. Sodium chloride, as table salt, is one of the most widely used chemicals in the world. It also has many industrial uses, such as serving as a raw material in the production of other chemicals. Sodium nitrite is a principle ingredient in gunpowder. The pulp and paper industry uses large amounts of sodium hydroxide, sodium carbonate, and sodium sul-

fate; the latter is utilized in the production of cardboard and brown paper. Sodium carbonate is used by power companies to absorb sulfur dioxide, a serious pollutant, from smokestack gases. It is also important to the glass and detergent industries. Sodium hydroxide is one of the top ten industrially produced chemicals, heavily used in manufacturing. Sodium bicarbonate (baking soda) is produced for the food industry as well.

Sodium also plays some important roles in living organisms. It regulates nerve transmission, alters cell membrane permeability, and

Sodium stored in oil to prevent its reaction with the surrounding air. *(Reproduced by permission of Photo Researchers, Inc.)*

performs many other tasks necessary for maintaining life. On the other hand, excesses of sodium can aggravate high blood pressure.

Potassium

Like sodium, potassium occurs most commonly in the form of the chloride, potassium chloride. It is present both in sea water and as a mineral known as sylvite in Earth's crust. Almost all the potassium used industrially goes into fertilizer. Other important compounds of potassium include potassium hydroxide, used in the manufacture of detergents; potassium chlorate, used for the production of explosives; and potassium bromide, an essential chemical in photography. Like sodium, potassium is a vital nutrient for organisms in a variety of ways.

Rubidium, cesium, and francium

Rubidium and cesium are much less common than are sodium and potassium, ranking numbers 23 and number 45, respectively, in abundance. Both elements also have relatively few practical applications. Rubidium is employed primarily in various kinds of chemical research. One of its compounds has been used to treat patients with depression. In addition, some kinds of glass and radiation detection equipment are made with cesium compounds.

Francium is a radioactive element (one that spontaneously gives off energy in the form of particles or waves by disintegration of their atomic nuclei) and is one of the rarest elements in Earth's surface. It has no uses except for research.

[*See also* **Element, chemical; Periodic table**]

Alkaline earth metals

The elements that make up Group 2 of the periodic table are commonly called the alkaline earth metals. They include beryllium, magnesium, calcium, strontium, barium, and radium. All of these elements contain two electrons in the outermost energy level of their atoms, and they tend to have similar chemical and physical properties. Their properties can also be compared to those of the alkali metals, which lie next to them on the periodic table. They are shiny, relatively soft, and white or silvery in color.

Like the alkali metals, the alkaline earth metals react with acids and water to produce hydrogen gas. These reactions, however, are less intense

than are those with the alkali metals. Alkaline earth metals also react vigorously with oxygen. Magnesium burns so actively in air, for example, that it is often used in flares because of the brilliant white light it produces during combustion.

Flame tests can be used to identify compounds of the alkaline earth metals. The characteristic colors of these elements are orangish-red for calcium, crimson for strontium, and apple-green for barium. The brilliant colors produced in fireworks displays are often produced by compounds of strontium and barium.

Beryllium

Beryllium ranks number 50 in abundance among the chemical elements. Interestingly enough, it occurs most commonly in gemstones and beautiful minerals such as beryl, emeralds, and aquamarine. The largest crystals of beryl are about a meter in length and weigh up to 60 metric tons.

The most important industrial application of beryllium is in the manufacture of alloys (metal mixtures). In very small amounts, the element adds strength, durability, and temperature stability to alloys. Copper-beryllium alloys make good hand tools in industries that use flammable solvents because the tools do not cause sparks when struck against other objects. Nickel-beryllium alloys are used for specialized electrical connections and various high temperature applications. Beryllium is used instead of glass in X-ray tubes because it lets through more of the X-radiation than glass would.

Beryllium is toxic to humans. Exposure to high concentrations can cause a pneumonia-like condition that can quickly result in death. Long-term exposure to even small concentrations can result in serious health problems, in particular a respiratory problem known as berylliosis.

Magnesium

Magnesium is the sixth most common element in Earth's crust. It occurs in minerals such as dolomite, magnesite, carnallite, asbestos, soapstone, mica, and spinel. The oceans also contain relatively high concentrations of magnesium chloride.

Magnesium performs a critical role in living things because it is a key component of chlorophyll. Chlorophyll is the green pigment that captures the energy of sunlight for storage in plant sugars during photosynthesis. (Through the process of photosynthesis, plants use light to break down chemical compounds). Chlorophyll is a large molecule called a

porphyrin; the magnesium occupies the center of the porphyrin molecule. In the animal kingdom, a similar porphyrin called heme allows hemoglobin to transport oxygen around in the bloodstream; in the case of heme, however, iron rather than magnesium occupies the central place in the porphyrin.

Elemental magnesium is a strong, light metal, particularly when alloyed, or mixed, with other metals like aluminum or zinc. These alloys have many uses in construction, such as in the manufacture of airplane

The White Cliffs of Dover, England, get their characteristic color from deposits of calcium carbonate. *(Reproduced by permission of JLM Visuals.)*

parts. Alloys of magnesium and the rare earth elements are so temperature resistant that they are used to make car engine parts.

Calcium

Calcium is the third most common metal on Earth, exceeded only by iron and aluminum, and the fifth most common element. Naturally occurring compounds of calcium include limestone, dolomite, marble, chalk, and iceland spar (all forms of calcium carbonate); gypsum (calcium sulfate); fluorite (calcium fluoride); and apatite (calcium fluorophosphate). Compounds of calcium are also found in sea water.

Calcium is an essential nutrient for living organisms. One of its function is the proper development of bones and teeth. Nutritionists say that growing children need about 1.5 grams of calcium every day to maintain good health. Calcium is also needed for the coagulation (clotting) of blood and for maintaining a normal heartbeat and blood pressure.

The industrial applications of calcium are numerous. Both limestone and gypsum have been used in building materials since ancient times; in general, gypsum was used in drier climates. Marble is also a good building material. Limestone and dolomite are the principle sources of slaked lime (calcium hydroxide) and quick lime (calcium oxide) for the steel, glass, paper, dairy, and metallurgical industries. Lime can act as an agent to remove impurities from steel, as a neutralizing agent for acidic industrial waste, as a reagent (a chemically active substance) for reclaiming sodium hydroxide from paper pulping waste, and as a scrubbing compound to remove pollutants from smokestack effluent. The paper industry uses calcium carbonate as an additive to give smoothness and opacity (the opposite of transparency) to the finished paper. The food, cosmetic, and pharmaceutical industries use it in antacids, toothpaste, chewing gum, and vitamins.

Strontium, barium, and radium

Strontium and barium are the fifteenth and fourteenth most abundant elements, respectively, in Earth's crust. They also occur in very small concentrations in the oceans. Radium is a radioactive element that occurs only in association with uranium, from which it is formed by radioactive decay. (A radioactive element is one that spontaneously gives off energy in the form of particles or waves by disintegration of their atomic nuclei.) This relationship between uranium and radium provides a reliable way to find the age of rocks. The larger the amount of radium in a rock, the longer decay has been taking place and the older the rock is.

Because of the brilliant red color they produce when burned, strontium compounds are widely used in fireworks and flares. Strontium carbonate is also a glass additive, and strontium hydroxide is a refining agent in the production of beet sugar. The most important commercial application of barium is in the form of barium sulfate, used as a lubricating mud in well-drilling operations. In the medical field, patients with gastrointestinal (stomach and intestinal) problems are often required to drink a chalky, white liquid form of barium sulfate before having X-ray examinations.

Radium was formerly used in medicine to treat various kinds of cancer and other conditions. Its use has declined, however, as safer radioactive materials have been discovered. Compounds of radium were also used to paint the luminous numbers on watch dials. That application has been stopped because of the health risks to workers who used the radium paint.

[*See also* **Chlorophyll; Element, chemical; Periodic table**]

Allergy

An allergy is an extreme or overly sensitive response of the immune system to harmless substances in the environment. The immune system launches a complex series of actions against an irritating substance, referred to as an allergen. This immune response may be accompanied by a number of stressful symptoms, ranging from mild to severe to life-threatening. In rare cases, an allergic reaction leads to anaphylactic shock—a condition characterized by a sudden drop in blood pressure, difficulty in breathing, skin irritation, collapse, and possible death.

The immune system may produce several chemical agents that cause allergic reactions. One example are the histamines released after exposure to an allergen. (Histamines are compounds that cause capillaries to dilate; smooth muscles to contract, thereby constricting airways; and gastric acids to be secreted.) The use of antihistamines helps to relieve some of the symptoms of allergy by blocking out histamine receptor sites in cells.

Types of allergy

The most common type of allergy is allergic rhinitis (inflammation of the mucous membrane of the nose) caused by inhaling allergens carried in the air. Seasonal environmental allergic rhinitis, or hay fever as it is popularly called, is brought on by wind-borne pollens, the dustlike masses of microscopic spores in seedbearing plants. Every spring, sum-

Words to Know

Allergen: An otherwise harmless substance that causes a fixed allergic response in certain people.

Anaphylactic shock: A violent, sometimes fatal, response to an allergen after initial contact.

Decongestant: Drug used for a short term to reduce mucous membrane congestion.

Histamine: Chemical produced by the immune system that triggers allergic reactions.

IgE: The chief antibody responsible for producing the compounds that cause allergic reactions.

Lymphocyte: A white blood cell that stimulates antibody formation.

Mast cell: A large cell in connective tissue containing substances involved in allergic reactions.

Receptor sites: Places on cells where substances bind to produce certain reactions.

Rhinitis: Nasal congestion, inflammation, and sneezing caused by seasonal pollens or other allergens.

Steroids: Drugs that stimulate the adrenal glands (which in turn secrete hormones, or chemical messengers that regulate various bodily functions) and are highly effective in treating asthma and allergies but also have many side effects.

Weal: A welt; the reddened, itchy swelling caused by a skin patch test.

mer, and fall, pollens from grasses, trees, and weeds produce allergic reactions—like sneezing, runny nose, swollen nasal tissues, headaches, blocked sinuses, and watery, irritated eyes—in allergy-prone people. Perennial allergic rhinitis is the year-round occurrence of symptoms caused by inhaling allergens such as animal dander, molds, and dust from dust mites. Of the 46 million allergy sufferers in the United States, about 25 million have rhinitis.

Other types of allergies can be traced to certain foods, drugs, insect bites, skin contact with chemical substances, and odors. In the United States there are about 12 million people who are allergic to a variety of

chemicals. In some cases an allergic reaction to an insect sting or a drug can cause sudden death. Serious asthma attacks are associated with seasonal rhinitis and other allergies. About 9 million people in the United States suffer from asthma.

Role of immune system

An individual's immune system plays a part in determining both the occurrence and the severity of allergic reactions. Some people are allergic to a wide range of allergens while others are allergic to only a few or to none. The immune system is the body's defense against substances it recognizes as foreign invaders. Lymphocytes, a type of white blood cell, fight viruses, bacteria, and other antigens (foreign substances such as toxins or enzymes) by producing antibodies. When an allergen first enters the body, the lymphocytes produce an antibody called immunoglobulin E

A scanning electron micrograph of a dust mite, a source of allergens that cause allergic reactions. *(Reproduced by permission of Phototake.)*

Anaphylaxis

Anaphylaxis is a sudden, severe, sometimes fatal allergic reaction to a foreign substance or antigen. In humans, anaphylaxis is a rare event in which an initial exposure to a certain substance—such as penicillin, an insect sting, or certain foods—creates extreme sensitivity to it. The body reacts to the allergen by producing specific immunoglobulin E (IgE) antibodies that attach to the surface of mast cells containing histamine. On subsequent exposure to the allergen, the antigen binds with the specific IgE antibodies, triggering the immediate release of histamine and other irritating chemicals by the mast cells. The release of these chemicals cause hives, itching, nasal congestion, a sudden drop in blood pressure, shock, or loss of consciousness. Swelling of the upper respiratory tract may result in severe difficulty breathing, which can lead to death.

Anaphylaxis must be treated immediately with an injection of adrenaline, followed by other medications. To prevent anaphylaxis, individuals with known sensitivities to certain substances are instructed to avoid exposure to them. Anaphylaxis kits are sometimes prescribed by doctors for patients who are hypersensitive to one or more antigens (a bee's sting, for instance). In the event of an emergency, the patients can inject themselves with adrenaline provided in the kit before getting to a doctor or hospital.

(IgE). The IgE antibodies attach to mast cells, large cells in connective tissue that contain histamines and other chemicals. The second time any given allergen enters the body, it becomes attached to the newly formed, Y-shaped IgE antibodies. These antibodies, in turn, stimulate the mast cells to release their histamines and other anti-allergen chemicals.

Studies show that allergy sufferers produce an excessive amount of IgE, indicating a hereditary factor in their allergic responses. How individuals adjust over time to allergens in their environment is also a factor in determining whether they will develop an allergic disorder.

Diagnosis and treatment

Diagnosis of an allergic disorder is based primarily on the patient's medical history. Skin patch tests are sometimes used to determine exactly

which allergens aggravate the patient's condition. A tiny amount of a suspected allergen is injected under the skin; any actual allergen will raise a weal at the site of the injection. The weal is a circular area of swelling that itches and is reddened. The size of the weal produced by a suspected allergen is compared to a "control" weal produced by the injection of histamine itself. The tests at times produce false positives, so they cannot be relied on exclusively.

The simplest form of treatment is avoidance of the allergic substance. When that is not possible, desensitization to the allergen is sometimes attempted by exposing the patient to gradually increasing quantities of the allergen at regular intervals.

Antihistamines, which are now prescribed and sold over the counter as an allergy remedy, were discovered in the 1940s. Antihistamines act by occupying the receptor sites in cells that react to histamine; histamine is therefore blocked from entering the sites. The allergens are still there, but the body's protective actions are suspended for the time the antihistamines are active. Antihistamines also constrict the smaller blood vessels and capillaries, thereby preventing the accumulation of excess nasal fluids.

Steroid drugs inhaled through the nose are sometimes prescribed to allergy sufferers to relieve local inflammation. Decongestants can also bring relief but should only be taken for a short time, since their continued use can make the allergy-sufferer's reaction more intense.

[*See also* **Antibody and antigen; Immune system**]

Alloy

An alloy is a mixture of two or more metals. Some familiar examples of alloys include brass, bronze, pewter, cast and wrought iron, steel, coin metals, and solder (pronounced SOD-der; a substance used to join other metallic surfaces together). Alloys are usually synthetic materials, developed by scientists for special purposes. They generally have specially desirable properties quite different from the metals from which they are made. As an example, Wood's metal is a mixture of about 50 percent bismuth, 10 percent cadmium, 13 percent tin, and 27 percent lead that melts at 70°C (160°F). This low melting point makes Wood's metal useful as a plug in automatic sprinkler systems. Soon after a fire breaks out, the heat from the flames melts the Wood's metal plug, releasing water from the sprinkler system.

Important Alloys, Their Composition, and Typical Uses

Alloy	Composition	Uses
Babbitt metal	tin: 90% antimony: 7% copper: 3%	used in bearings because of its low measure of friction with steel
bell metal	copper: 77% tin: 23%	casting of bells
brass	copper with up to 50% zinc	inexpensive jewelry; hose nozzles and couplings; piping; stamping dies
bronze	copper with up to 12% tin	coins and medals; heavy gears; tools; electrical hardware
coin metal	copper: 75% nickel: 25%	U.S. coins
duralumin	aluminum: 95% copper: 4% manganese: <1% magnesium: 0.5%	aircraft, boats, railroad cars, and machinery because of its high strength and resistance to corrosion
monel	nickel: 60% copper: 33% iron: 7%	corrosion-resistant containers
Nichrome®	nickel: 80-85% chromium: 15-20%	heating elements in toasters, electric heaters, etc.
phosphor bronze	bronze with a small amount of phosphorus	springs, electrical springs, boat propellers
solder	lead: 50% tin: 50%	joining two metals to each other
sterling silver	silver: 92.5% copper: 7.5%	jewelry, art objects
type metal	lead: 75–95% antimony: 2–18% tin: trace	used to make type for printing because it expands as it cools

Alternative energy sources

Alternative energy is energy provided from sources other than the three fossil fuels: coal, oil, and natural gas. Alternative sources of energy include

Words to Know

Active solar heating: A solar energy system that uses pumps or fans to circulate heat captured from the Sun.

Fossil fuel: A fuel such as coal, oil, or natural gas that is formed over millions of years from the remains of plants and animals.

Heat energy: The energy produced when two substances that have different temperatures are combined.

Passive solar heating: A solar energy system in which the heat of the Sun is captured, used, and stored by means of the design of a building and the materials from which it is made.

Photovoltaic cell: A device made of silicon that converts sunlight into electricity.

Radioactivity: The property possessed by some elements of spontaneously emitting energy in the form of particles or waves by disintegration of their atomic nuclei.

Solar collector: A device that absorbs sunlight and collects solar heat.

Turbine: An engine that turns in a circular motion when force, such as moving water, is applied to its parts.

nuclear power, solar power, wind power, water power, and geothermal energy, among others.

Current sources of energy

As of the beginning of the twenty-first century, fossil fuels (fuels formed over millions of years from the remains of plants and animals) provide more than 85 percent of the total energy used around the world. In the United States, two-thirds of the electricity is currently generated by burning fossil fuels like coal, gas, and oil. According to the U.S. Department of Energy and the Environmental Protection Agency, such combustion pumped almost 2.5 billion tons (2.3 billion metric tons) of carbon dioxide into the atmosphere in 1999. Over the last 150 years. some 270 billion tons (245 billion metric tons) of carbon in the form of carbon dioxide have been released into the air as a result of the burning of fossil fuels.

Fossil fuels supply energy for transportation, industrial manufacturing, heating of buildings, and the production of electricity. However, the

reserves of coal, oil, and natural gas are limited; in fact, they are called nonrenewable resources because once the supplies that are available are used up, they cannot be replaced. It is predicted that at the current rate of energy consumption, available reserves of oil and natural gas will be greatly decreased during the twenty-first century. Coal is more plentiful, but its use can contribute to environmental problems such as global warming (an increase in Earth's temperature over time). Because of growing energy demands in developing nations as well as the energy needs of industrialized societies, it will become increasingly necessary to turn to alternative sources of energy in the future. Conserving energy and using it more efficiently are additional ways of addressing the energy problem.

Nuclear power

Nuclear power is an alternative energy source that can be obtained from either the splitting of the nuclei of atoms (nuclear fission) or the combining of the nuclei of atoms (nuclear fusion). In either of these two reactions, great amounts of energy are released. Nuclear power plants use a device called a nuclear reactor in which uranium or plutonium atoms are split in controlled fission reactions. The heat energy released is captured and used to generate electricity. As of 2000, there were 110 operating nuclear power plants in the United States. France relies on nuclear power for more than 70 percent of its electricity production.

Controlled nuclear fusion is believed by many scientists to be the ultimate solution to the world's energy problems. The energy released in fusion reactions is many times greater than that released in fission reactions. To date, however, the technology has not been developed to make use of this source of energy.

Although nuclear power is a clean, cheap, and relatively safe means of providing energy, public concern over safety issues has brought the construction of new nuclear power plants to a virtual halt in the United States. The nuclear accidents at Three Mile Island in Pennsylvania in 1979 and at the Chernobyl nuclear power plant in Ukraine in 1986 (in which a large amount of radioactive material was released into the atmosphere) prompted fears of similar disasters occurring elsewhere. In addition, there is the problem of storing radioactive nuclear waste safely so that it does not pose a threat to humans or the environment.

Water power

The power of moving water, or hydropower, is a clean and efficient means of generating electricity. Water falling through dams powers

water turbines that are hooked up with electric generators. The energy is then distributed across vast electrical networks. Canada, the United States, and Brazil lead the world in hydroelectricity production. The building of dams has an environmental impact, however, causing flooding of land above the dams and disrupting the normal flow of water below them, which can affect the natural ecosystem (a community of organisms and their environment) of a river.

Wind power

Wind power is one of the earliest forms of energy used by humankind. Windmills were used on farms in the early part of the twentieth century to pump water and generate electricity. Now considered an alternative energy source, wind power is being harnessed by modern windmills with lighter, stronger blades. In states such as California, New Hampshire, Oregon, and Montana, up to several hundred windmills may operate together (called wind farms) in open areas with steady winds. Single giant windmills capable of providing electricity to several thousand homes are also operating in the United States. Several power companies have plans to build large-scale wind farms in Texas, New Jersey, Massachusetts, and Minnesota, and smaller plants in Pennsylvania, Connecti-

The wind power captured by these turbines at Tehachapi Pass, California, is a source of energy that does not harm the environment. *(Reproduced by permission of the U.S. Department of Energy.)*

cut, and New York before 2020. By that year, the U.S. Department of Energy hopes the contribution of wind power to electrical generation nationwide will be increased by 5 percent. With new technologies being developed to improve windmill performance and efficiency, wind power is a promising, clean, cheap, and abundant source of energy for the future.

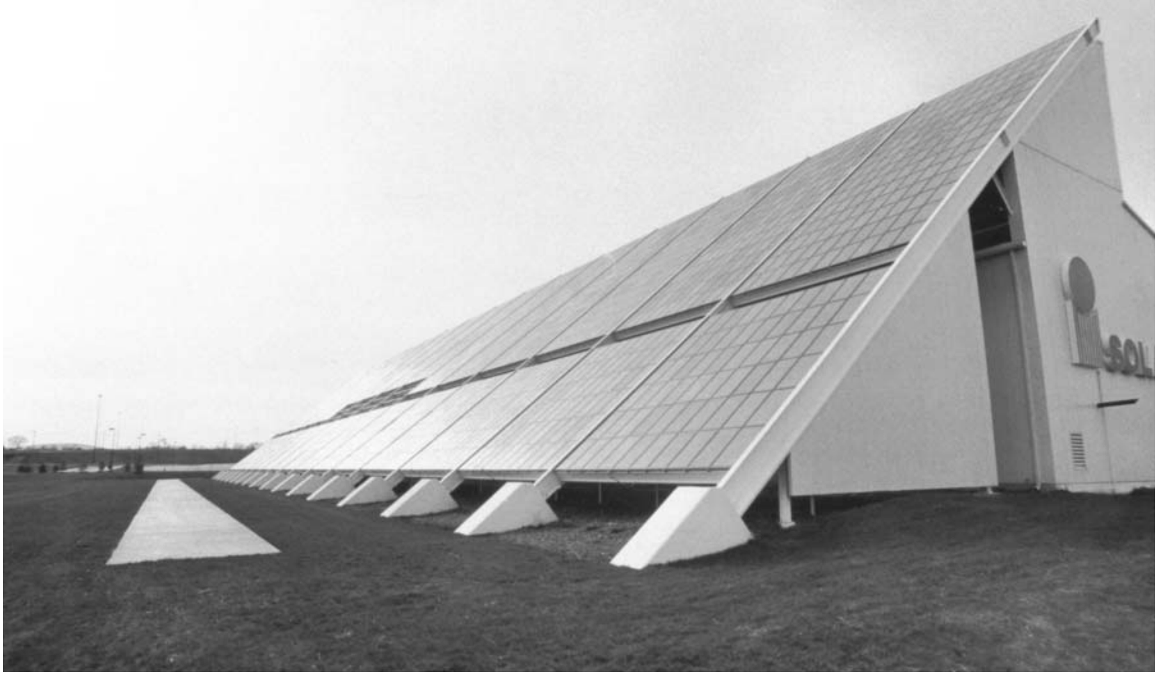
Solar power

Solar power, or energy from the Sun, is a free, abundant, and nonpolluting source of energy. Solar energy can be used to heat buildings and water and to produce electricity. However, the Sun does not always shine, and the process of collecting solar energy and storing it for use at night and on cloudy days is difficult and expensive.

Solar energy systems can be either passive or active. In a passive solar heating system, a building captures and stores the Sun's heat because of the way it is designed, the materials it is made of, or the heat-absorbing structures it possesses. An example of a passive system is a building with large windows facing south (that allow sunlight to enter) and with thick walls that store heat and release it at night.

Active solar energy systems use pumps or fans to circulate heat obtained by solar collectors. A solar collector is a device that absorbs the

A building sided with photovoltaic cells, which capture the energy of the Sun and convert it into electrical energy. *(Reproduced courtesy of the Library of Congress.)*



energy of the Sun and converts it to heat for heating buildings and water. Flat-plate collectors are mounted to the roofs of buildings and used for space heating. They are made of a heat-absorbing plate, such as aluminum or copper, covered by glass or plastic. Water or air circulating in the collector absorbs heat from the plate and is carried to a heat storage tank. The stored heat is circulated or blown over cold rooms using pumps or fans. A conventional heating system is used as a backup when solar heat is not available. Solar heating of water is accomplished using a collector, a hot water storage tank, and a pump to circulate water.

Sunlight can be captured and converted into electric power using solar cells (called photovoltaic cells). Solar cells are usually made up of silicon and can convert light to electric current. They are used in space satellites to provide electricity, as well as in watches and pocket calculators. Solar panels made up of solar cells have been installed in some homes, and solar cells are used as energy sources in lighthouses, boats, and other remote locations.

Solar power plants—using energy from the Sun to produce steam for driving turbines to generate electricity—could potentially replace fuel-driven power plants, producing energy without any environmental hazards. In California, a solar power facility—using collectors made of large motorized mirrors that track the Sun—produces electricity to supplement the power needs of the Los Angeles utilities companies.

Geothermal energy

Geothermal energy is the natural heat generated in the interior of Earth and released from volcanoes and hot springs or from geysers that shoot out heated water and steam. Reservoirs of hot water and steam under Earth's surface can be accessed by drilling through the rock layer. The naturally heated water can be used to heat buildings, while the steam can be used to generate electricity. Steam can also be produced by pumping cold water into rock that is heated by geothermal energy; such steam is then used to produce electric power.

Geothermal energy is an important alternative energy source in areas of geothermal activity, including parts of the United States, Iceland, and Italy. Homes in Boise, Idaho, are heated using geothermal energy, as are most buildings in Iceland. The Geysers in California is the largest steam field in the world and has been used to produce electricity since 1960. Unlike solar energy and wind power, however, the use of geothermal energy has an environmental impact. Chemicals in the steam contribute to air pollution, and water mixed with the steam contains dissolved salts that can corrode pipes and harm aquatic ecosystems.

Tidal and ocean thermal energy

The rise and fall of ocean tides contain enormous amounts of energy that can be captured to produce electricity. In order for tidal power to be effective, however, the difference in height between low and high tides needs to be at least 20 feet (6 meters), and there are only a few places in the world where this occurs. A tidal station works like a hydropower dam, with its turbines spinning as the tide flows through them in the mouths of bays or estuaries (an arm of the sea at the lower end of a river), generating electricity. By the end of the twentieth century, tidal power plants were in operation in France, Russia, Canada, and China.

Ocean thermal energy uses the temperature change between the warmer surface waters and the colder depths to produce electrical power.

Biomass energy

Certain biomass (the sum total of living and dead plants, animals, and microorganisms in an area) can be used as fuel to produce heat energy. Wood, crops and crop waste, and wastes of plant, mineral, and animal matter are part of the biomass. The biomass contained in garbage can be burned to produce heat energy or can be allowed to decay and produce methane (natural gas). In western Europe, over 200 power plants burn rubbish to produce electricity. Methane can be converted to the liquid fuel methanol, and ethanol can be produced from fermentable crops such as sugar cane and sorghum. Adequate air pollution controls are necessary when biomass is burned to limit the release of carbon dioxide into the atmosphere.

Other sources of alternative energy

Other sources of alternative energy include hydrogen gas and fuel cells. Hydrogen gas is a potential source of fuel for automobiles, as well as a potential source of energy for heating buildings and generating electricity. Although hydrogen is not readily available, it can be produced by separating water into hydrogen and oxygen in a process called electrolysis. A disadvantage of using hydrogen gas as fuel is that it is highly flammable.

Fuel cells are devices that produce electric power from the interaction of hydrogen and oxygen gases. They are used to provide electricity in spacecraft and are a potential alternative energy source for heating buildings and powering automobiles.

Energy conservation

Energy conservation plays an extremely important role in reducing unnecessary energy consumption. Improving energy efficiency is the best

way to meet energy demands without adding to air and water pollution. Designing gas-saving automobiles, using fluorescent lightbulbs, recycling, raising the setting for house air conditioners, improving the efficiency of appliances, and properly insulating buildings are some of the ways energy can be conserved.

[*See also* **Bioenergy; Pollution; Pollution control; Waste Management**]

Alternative medicine

Alternative medicine is the practice of techniques to treat and prevent disease that are not generally accepted by conservative modern Western medicine. These techniques include homeopathy, acupuncture, herbal medicine, yoga, meditation, chiropractic, massage therapy, biofeedback, naturopathy, and many others. Although some of these forms such as yoga, meditation, and acupuncture have been practiced for centuries in many cultures, the U.S. medical community has been slow to acknowledge their benefits.

With an increased emphasis on disease prevention in recent years, many people have looked to alternative forms of medicine for drug-free approaches to achieving and maintaining good health. Alternative medicine allows people a measure of participation and control in their own well-being, as many of the practices can be taught and self-administered. Some people have turned to alternative medicine in search of treatment or cures for illnesses such as cancer, AIDS (acquired immunodeficiency syndrome), arthritis, and heart disease.

Relaxation techniques

Relaxation techniques help promote sleep, reduce stress, and alleviate pain. Controlled breathing is the simplest form of relaxation and consists of sitting or lying in a quiet place and breathing slowly in through the nose and out through the mouth. An advantage of this technique is that, if needed, it can be performed at any time, in any location, to produce relaxation.

Progressive relaxation therapy is a method of relieving muscle tension. Quietly lying on one's back and focusing on a particular region of the body such as the face, the individual consciously relaxes the muscles in that area. Moving through each part of the body, the individual repeats the process until all the body's muscles are relaxed.

The ancient practice of yoga incorporates relaxation, deep breathing, and postures (placing the body in certain positions) to relieve stress, improve blood circulation, and strengthen the body. Regular practice of yoga has been shown to be helpful in reducing the symptoms of many ailments from depression to heart disease.

Meditation is a method of relaxation in which a person concentrates his mind on a single thing such as an image, a word or phrase repeated silently, or the pattern of his breath. Meditation is usually practiced in a sitting position with the eyes closed and the back held straight. Its immediate benefits are reduced stress and anxiety, lowered blood pressure, and a slower rate of breathing. The daily practice of meditation over a long period of time has been shown to strengthen the body's ability to fight disease.

Biofeedback is a relaxation technique in which an individual learns to consciously control certain body functions—for example, blood pressure. The individual is connected by electrodes to a machine that responds to body signals (blood pressure in this case) by beeping. Increased blood pressure results in a faster series of beeps, which slow as blood pressure decreases. As the beeps slow down, the person realizes that the blood pressure has decreased and tries to remember the relaxed state that created the change. The ultimate goal is to be able to recreate the relaxed state that lowered blood pressure—without the aid of signals. Biofeedback has been used to treat migraines, to improve digestion, to lower heart rate, and to relieve pain. It has also been used to regain some control of muscles in persons who are partially paralyzed.

Hypnotherapy is the use of hypnosis to help a person gain control over stress, pain, and bad habits such as smoking and overeating. It is also sometimes used in medicine to block the sensation of pain during medical procedures and in psychotherapy to assist patients in recalling traumatic events. Under the guidance of a hypnotherapist, the person enters a trancelike state during which his subconscious mind responds to the suggestions of the therapist. The person can be taught to recreate the deeply relaxed state he experienced while under hypnosis and to use it on his own to overcome pain, control eating and smoking habits, and reduce stress.

Visualization and guided imagery are additional relaxation techniques that involve focusing the mind on specific images. With eyes closed, the person pictures in his mind a peaceful image or scene and concentrates on the sights, sounds, and smells that make the image soothing. Visualization is sometimes used as a supplemental treatment for patients with cancer or other serious and painful diseases. Guided by a therapist,

the patient may visualize his body fighting the disease. This technique has been credited with bringing about physical healing in some cases.

Massage therapy is a method of achieving relaxation by applying pressure to and kneading the muscles of the body. Under the hands of a skilled massage therapist, this relaxation technique can temporarily relieve muscle tension and mental stress.

Chiropractic

Chiropractic is a medical practice founded on the theory that human disease is caused by impaired nerve functioning. This impairment stems from the vertebrae of the spine shifting from their normal place and putting pressure on the spinal nerves. To treat a patient, the chiropractor massages and manipulates the vertebrae back to their proper position.

Holistic medicine

Holistic medicine is an approach to health care that takes into consideration the whole person in the treatment and prevention of disease. According to practitioners of the holistic approach, a person's physical, mental, emotional, and spiritual states must all be in harmony for optimal health. Many licensed doctors practice holistic medicine, and they may include alternative forms of therapy in place of or in addition to traditional forms in treating patients.

Herbal medicine

Herbal medicine uses herbal remedies composed of plant substances to treat illness. Herbs have been used for centuries in most cultures of the world, and many drugs used in modern Western medicine are derived from plants. Herbal remedies can be taken as capsules or as tinctures (plant extracts in alcohol). Fresh or dried herbs can be brewed for teas, applied directly, or mixed with water and used as pastes to treat skin disorders. Herbal remedies are often prescribed by alternative medical practitioners as part of a treatment program that includes proper diet, exercise, and relaxation techniques.

Homeopathy

Homeopathy is a term derived from the Greek words meaning "similar suffering." A system of medicine developed over 200 years ago, homeopathy is based upon the principle that "like cures like." To treat a disease or disorder, the homeopath practitioner prescribes a remedy (an extract of plant, mineral, or animal substances) that produces the same

Acupuncture and Acupressure

Acupuncture is a technique developed by the ancient Chinese in which very thin needles are inserted through the skin at specific points of the body to relieve pain, cure disease, or provide anesthesia for surgery. The technique is one element of traditional Chinese medicine, which also includes herbal remedies, massage therapy, and a healthful diet. Acupuncture is practiced in the United States by both medical doctors and licensed practitioners, although its use by physicians is mostly limited to pain relief.

According to Chinese belief, lines or channels of energy cover the body and flow through it. The presence of illness or disease indicates that the flow of energy is blocked. Inserting fine needles at precise points along the channels removes the blockage, restoring the free flow of energy and allowing the internal organs to correct imbalances in their functioning.

Acupressure, also called shiatsu in Japan, is an ancient Chinese method of improving a person's health by applying pressure to specific points on the body. Acupressure uses the same channels of energy flow as acupuncture but does not break the skin. Instead, the acupressure practitioner applies pressure using the fingertips or knuckles to loosen muscles and improve circulation.

symptoms the patient is experiencing. The remedy would make a healthy person sick, but in a sick person the remedy is thought to stimulate the body's natural defenses and promote healing.

In homeopathy, it is believed that each individual's illness is unique to that person, and both the person's physical and mental states are considered before prescribing a remedy. Like many other alternative medicine practices, homeopathy treats the body and mind as one; what affects one affects the other.

Homeopathy is a respected and approved medical practice in parts of Europe, Latin America, India, Greece, South America, and South Africa. In the United States, homeopathy has only begun to be accepted by the mainstream medical community, with some physicians using it along with traditional medicine to treat their patients. The production of homeopathic remedies is regulated by the Food and Drug Administration, and the remedies are available in many natural food stores.

Naturopathy

Founded in the early part of the twentieth century, naturopathy is a system of healing disease using natural means. This drug-free method of treating patients relies on natural means such as manual manipulation, homeopathy, herbal medicine, hydrotherapy (water therapy), massage, exercise, and nutrition. The body's power to heal is acknowledged to be a powerful process that the practitioner, or naturopath, seeks to enhance using all-natural remedies that appear to help the patient.

Naturopaths are trained practitioners who diagnose and treat disease and are licensed in a number of states. They are specialists in preventive medicine who teach patients how to live in ways that maintain good health. Naturopaths sometimes work with physicians to help patients recover from major surgery. Although naturopathy is not widely accepted in the medical community, some physicians are also naturopaths.

Aluminum family

The aluminum family consists of elements in Group 13 of the periodic table: boron (B), aluminum (Al), gallium (Ga), indium (In), and thallium (Tl). The family is usually named after the second element, aluminum, rather than the first, boron, because boron is less typical of the family members than is aluminum. Boron is a metalloid (an element that has some of the properties of metals and some of the properties of nonmetals), while the other four members of the family are all metals.

Aluminum

Aluminum is a lightweight, silvery metal, familiar to every household in the form of pots and pans, beverage cans, and aluminum foil. It is attractive, nontoxic, corrosion-resistant, nonmagnetic, and easy to form, cast, or machine into a variety of shapes. It has a melting point of 660°C (1,220°F) and a boiling point of 2,519°C (4,566°F).

Aluminum is the third most abundant element in Earth's crust after oxygen and silicon, and it is the most abundant of all metals. It constitutes 8.1 percent of the crust by weight and 6.3 percent of all the atoms in the crust. Because it is a very active metal, aluminum is never found in its metallic form. Rather, it occurs in a wide variety of earthy and rocky minerals, including feldspar, mica, granite, and clay. Kaolin is an especially fine, white, aluminum-containing clay that is used in making porcelain.

Known as aluminium in other English-speaking countries, the element was named after the mineral alum, one of its salts that has been known for thousands of years. Alum was used by the Egyptians, Greeks, and Romans as a mordant, a chemical that helps dyes stick to cloth.

Properties and uses. Pure aluminum is relatively soft and not the strongest of metals. When melted together with other elements such as copper, manganese, silicon, magnesium, and zinc, however, it forms alloys (a substance composed of two or more metals or of a metal and a nonmetal) with a wide range of useful properties. Aluminum alloys are used in airplanes, highway signs, bridges, storage tanks, and buildings. The world's tallest buildings, the World Trade Center towers in New York, are covered with aluminum. Aluminum is being used more and more in automobiles because it is only one-third as heavy as steel and therefore decreases fuel consumption.

In spite of the fact that aluminum is chemically very active, it does not corrode in moist air the way iron does. Instead, it quickly forms a thin, hard coating of aluminum oxide. Unlike iron oxide or rust, which flakes off, the aluminum oxide sticks tightly to the metal and protects it from further oxidation. The oxide coating is so thin that it is transparent, so the aluminum retains its silvery metallic appearance. Sea water, however, will corrode aluminum unless it has been given an unusually thick coating of oxide by the anodizing process. (During the anodizing process, a piece of aluminum is oxidized in order to create on its surface a coating of aluminum oxide, which is able to take dyes, unlike plain aluminum.)

When aluminum is heated to high temperatures in a vacuum, it evaporates and condenses onto any nearby cool surface such as glass or plastic. When evaporated onto glass, it makes a very good mirror. Aluminum has largely replaced silver in the production of mirrors because it does not tarnish and turn black as silver does when exposed to impure air. Many food-packaging materials and shiny plastic novelties are made of paper or plastic with an evaporated coating of bright aluminum. The silver-colored helium balloons popular at birthday parties are made of a tough plastic called Mylar™, covered with a thin, evaporated coating of aluminum metal.

Aluminum is one of the best conductors of electricity, with a conductivity about 60 percent that of copper. Because it is also light in weight and highly ductile (able to be drawn out into thin wires), it is used instead of copper in almost all of the high-voltage electric transmission lines in the United States.

Aluminum is used to make kitchen pots and pans because of its high heat conductivity. It is handy as an airtight and watertight food wrapping

because it is very malleable; it can be pressed between steel rollers to make foil (a thin sheet) less than one-thousandth of an inch thick. Claims are occasionally made that aluminum is toxic and that aluminum cookware is therefore dangerous, but no clear evidence for this belief has ever been found. Many widely used over-the-counter antacids contain thousands of times more aluminum (in the form of aluminum hydroxide) than a person could ever get from eating food cooked in an aluminum pot. Aluminum is the only light element that has no known physiological function in the human body.

Production. As a highly reactive metal, aluminum is very difficult to separate from other elements that are combined with it in its minerals and compounds. In spite of its great abundance on Earth, the metal itself remained unknown for centuries. In 1825, some impure aluminum metal was finally isolated by Danish physicist Hans Christian Oersted (1777–1851) by treating aluminum chloride with potassium amalgam (potassium dissolved in mercury). Then, in 1827, German chemist Hans Wöhler (1800–1882) obtained pure aluminum by the reaction of metallic potassium with aluminum chloride. He is generally given credit for the discovery of elemental aluminum.

But it was still very expensive to produce aluminum metal in any quantity, and for a long time it remained a rare and valuable metal. In 1852, aluminum was selling for about $545 a pound. The big breakthrough came in 1886, when Charles M. Hall, a 23-year-old student at Oberlin College in Ohio, and Paul L-T. Héroult, another college student in France, independently invented what is now known as the Hall or Hall-Héroult process. This process consists of dissolving alumina (aluminum oxide) in melted cryolite, a common aluminum-containing mineral, and then passing an electric current through the hot liquid. Molten aluminum metal collects at the cathode (negative electrode). Not long after the development of this process, the price of aluminum metal plummeted to about 30 cents a pound. The process used to extract aluminum from its ores today is essentially the same as that developed by Hall and Héroult 150 years ago.

Boron

Elemental boron occurs in a variety of forms, ranging from clear red crystals to a black or brown powder to a transparent black crystal that is nearly as hard as diamond. The element is never found free in nature but is extracted commercially from minerals such as borax, ulexite, colemanite, and kernite. Boron is a relatively rare element, constituting about 0.001 percent of Earth's crust. It ranks number 38 in abundance, after nitrogen, lithium, and lead, but before bromine, uranium, and tin.

Properties and uses. The physical properties of boron are somewhat difficult to determine since the element occurs in so many different forms. The melting point of its most stable form is given as 2,180°C (3,900°F) (the second highest after carbon); its boiling point is about 3,650°C (6,600°F).

Chemically, boron is a fascinating element. One text on the chemical elements claims that the inorganic chemistry of boron is "more diverse and complex than that of any other element in the periodic table." The element forms five types of compounds: (1) metal borides (a metal plus boron), (2) boron hydrides (boron plus hydrogen), (3) boron trihalides (boron plus a halide; a halide is a simple halogen compound), (4) oxo compounds (boron plus complex oxygen radicals; a radical is a group of atoms that behaves as a unit in chemical reactions but is not stable except as part of the compound), and organoboron compounds (boron combined with an organic, or carbon-containing, component).

Boron itself has relatively few uses aside from its role in nuclear reactors as a neutron absorber and in alloys as a hardening agent. (Nuclear reactors are devices used to control the energy released from nuclear reactions.) It is also used in the manufacture of semiconductors. (Semiconductors are substances that conduct an electric current but do so very

Aluminum alloy framing on a building. *(Reproduced by permission of JLM Visuals.)*

poorly.) Probably its best known compound, borax, is used as a water softening agent, in the production of glasses and ceramics, and as an herbicide. A compound derived from borax—boric acid—is used as an eyewash and in the production of heat-resistant glass.

Two boron compounds of special interest are boron carbide and boron nitride. Both are used as refractories, substances that are highly resistant to heat. The melting point of boron carbide is about 2,350°C (4,230°F) and that of boron nitride, over 3,000°C (5,400°F). When boron nitride powder is compressed at very high pressures, it produces a hard crystalline material that is as hard as natural diamonds.

Gallium, indium, and thallium

For most of its history, gallium was best known for one unusual physical property: it has a melting point of 29.76°C (85.6°F), less than that of the human body. If you were to hold a lump of gallium metal in your hand, therefore, it would melt.

In spite of this fact, gallium and its compounds have traditionally had few uses—until recently. In the 1970s, a compound of gallium called gallium arsenide was found to have semiconductor properties. Gallium arsenide has also been used extensively in light-emitting diodes (LEDs), which are used in the electronic displays of calculators, watches, and CD players.

Neither indium nor thallium has many commercial applications. The former element is used largely in making alloys and in the production of transistors and photo cells. A radioactive isotope of the latter, thallium-201, is used in medical diagnostic studies, especially those involving the function of the circulatory system.

[*See also* **Periodic table; Transistor**]

Alzheimer's disease

Alzheimer's is a brain disease in which damaged and dying brain cells cause devastating mental deterioration over a period of time. Often confused with senility (mental and physical deterioration associated with old age), its symptoms include increasingly poor memory, personality changes, and loss of concentration and judgment. The disease affects approximately four million people in the United States. Although most victims are over age 65, Alzheimer's disease is not a normal result of aging.

Words to Know

Beta amyloid protein: A protein that accumulates in the brains of Alzheimer's disease victims.

Neocortex: The deeply folded outer layer of the cerebrum, controlling higher brain functions such as memory, speech, and thought.

Neurofibrillary tangle: An abnormal collection of bunched and twisted fibers found in dying neurons.

Proteins: Large molecules that are essential to the structure and functioning of all living cells.

Senility: Mental and physical deterioration of old age once considered a normal process of aging.

Medication can relieve some symptoms in the early stages of the disease, but there is no effective treatment or cure. Its exact cause remains unknown.

History

Alzheimer's disease is named after German neurologist Alois Alzheimer (1864–1915), who was the first to describe it. In 1906, he studied a 51-year-old woman whose personality and mental abilities were obviously deteriorating: she forgot things, became paranoid, and acted strangely. After the woman's death, Alzheimer examined her brain at autopsy (examination of a dead body to find the cause of death or investigate the damage produced by disease) and noted an unusual thickening and tangling of the organ's nerve fibers. He also found that the cell body and nucleus of nerve cells had disappeared. Alzheimer noted that these changes indicated some new, unidentified illness. More than seven decades would pass before researchers again turned their attention to this puzzling, destructive disease.

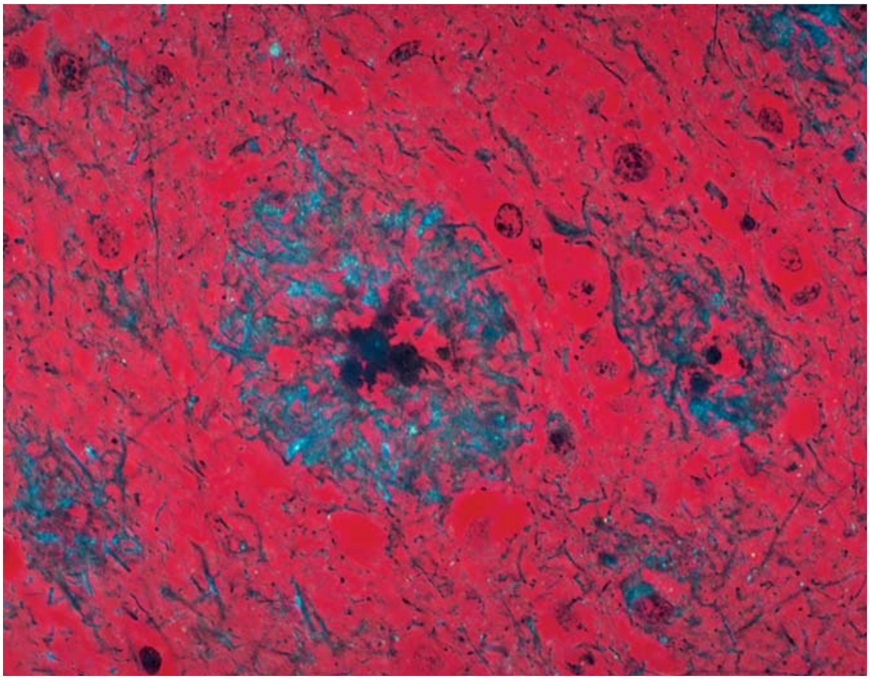
A progressive disorder

Alzheimer's is a tragic disease that slowly destroys its victim's brains, robbing them of the thoughts and memories that make them unique human beings. Patients with Alzheimer's typically progress through a

series of stages that begin with relatively minor memory loss of recent events. Gradually, loss of memory is accompanied by forgetfulness, inattention to personal hygiene, impaired judgment, and loss of concentration. Later symptoms include confusion, restlessness, irritability, and disorientation. These conditions worsen until patients are no longer able to read, write, speak, recognize loved ones, or take care of themselves. Survival after onset of symptoms is usually five to ten years but can be as long as twenty years. Persons with Alzheimer's are especially vulnerable to infection (particularly pneumonia), which is the usual cause of death.

Changes in the brain

A healthy brain is composed of billions of nerve cells (neurons), each consisting of a cell body, dendrites, and an axon. Dendrites and axons together are called nerve fibers and are extensions of the cell body. Nerve messages enter a neuron by way of the dendrites and leave by way of the axon. Neurons are separated from one another by narrow gaps called synapses. Messages traveling from one neuron to another are carried across these narrow gaps by chemicals called neurotransmitters. This highly organized system allows the brain to recognize stimuli and respond in an appropriate manner.



Diseased tissue from the brain of an Alzheimer's patient showing abnormal plaques within the brain's gray matter. *(Reproduced by permission of Photo Researchers, Inc.)*

In Alzheimer patients, this orderly system becomes damaged to such a degree that it no longer works. The brains of Alzheimer's patients examined at autopsy show two hallmark features: (1) a mass of fibrous structures called neurofibrillary tangles and (2) plaques consisting of a core of abnormal proteins embedded in a cluster of dying nerve endings and dendrites. Lowered levels of the neurotransmitter acetylcholine (pronounced uh-seh-tuhl-KOH-leen) are also observed. The brains of Alzheimer's disease victims appear shrunken, particularly in large parts of the neocortex, the outer layer of gray matter responsible for higher brain functions such as thought and memory. Much of the shrinkage of the brain is due to loss of brain cells and decreased numbers of connections, or synapses, between them.

Diagnosing Alzheimer's disease. There is no simple procedure, such as a blood test, to diagnose Alzheimer's. A definitive diagnosis can only be made by examining brain tissue after death. Diagnosis in a live patient is based on medical history, physical examination, laboratory tests to rule out other possible causes of symptoms, and neurological exams to test mental performance. Using these methods, physicians can accurately diagnose 90 percent or more of cases.

Risk factors for Alzheimer's disease. The specific cause of Alzheimer's disease remains unknown, although risk factors include advanced age, trauma such as head injury, and gene mutations. (Genes are the units of inheritance, and mutations are permanent changes to them.) When the disorder appears in a number of family members, it is called familial Alzheimer's disease and is thought to be caused by an altered gene. Scientists are exploring the metal aluminum as a possible toxic agent involved in the development of Alzheimer's. Also being studied is the role of the neurotransmitter acetylcholine, as declining levels of this chemical result in more severe symptoms of the disease. Some scientists believe the abnormal proteins found in plaques in the brains of Alzheimer's victims may be the key to understanding the disease. Yet another factor being studied as a possible cause is a slow-acting virus.

A growing problem

The Alzheimer's Association, a nonprofit research and support organization based in Chicago, estimates that more than 100,000 Americans die of Alzheimer's each year, making it the fourth leading cause of death among adults in the United States (after heart disease, cancer, and stroke). The cost of caring for Alzheimer's patients is projected to be $80 to $90 billion per year. As more and more citizens live into their

eighties and nineties, the number of Alzheimer's disease cases could reach 14 million or more before the middle of the twenty-first century.

[*See also* **Aging and death; Brain; Dementia; Nervous system**]

Amino acid

Amino acids are simple organic compounds made of carbon, hydrogen, oxygen, nitrogen, and, in a few cases, sulfur. Amino acids bond together to form protein molecules, the basic building blocks of all living things. Amino acids can vary widely. Only about 20 amino acids are common in humans and animals, with 2 additional ones present in a few animal species. There are over 100 lesser known amino acids found in other living organisms, particularly plants.

The first few amino acids were discovered in the early 1800s. Although scientists determined that amino acids were unique compounds, they were unsure of their exact significance. Scientists did not understand their importance in the formation of proteins—chemical compounds responsible for the structure and function of all cells—until the first part of the twentieth century.

Bonding

An important characteristic of amino acids is their ability to join together in chains. The chains may contain as few as 2 or as many as 3,000 amino acid units. Amino acids become proteins when 50 or more are bonded together in a chain.

All the millions of different proteins in living things are formed by the bonding of only 20 amino acids. Like the 26 letters of the alphabet that join together to form different words, the 20 amino acids join together in different combinations and sequences to form a large variety of proteins. But whereas most words are formed by about 10 or fewer letters, proteins are formed by 50 to more than 3,000 amino acids. Because each amino acid can be used many times along the chain and because there are no restrictions on the length of the chain, the number of possible combinations for the formation of protein is truly enormous.

The order of amino acids in the chain, however, is extremely important. Just as not all combinations of letters make sense, not all combinations of amino acids make functioning proteins. Some amino acid combinations can cause serious problems. Sickle-cell anemia is a serious,

Words to Know

Essential amino acid: Amino acid that cannot be produced by the human body and must be obtained from the diet.

Non-essential amino acid: Amino acid that is produced within the human body.

Proteins: Organic substances consisting of amino acids and other elements that form the basis of living tissues.

sometimes fatal disease caused by a single amino acid being replaced by a different one at the sixth position from the end of the protein chain in the hemoglobin molecule, the oxygen-carrying particle in red blood cells.

Human need for amino acids

The 20 amino acids required by humans for making protein are necessary for the growth and repair of tissue, red blood cells, enzymes, and other materials in the body. Twelve of these amino acids, called non-essential amino acids, can be made within the body. The other eight, called the essential amino acids, cannot be made by the body and must be obtained from the diet. Proteins from animal sources—meat, eggs, milk, cheese—contain all the essential amino acids. Except for soybeans, vegetable proteins do not have all the essential amino acids. Combinations of different vegetables, however, form a complete source of essential amino acids.

[*See also* **Nutrition; Proteins**]

Amoeba

An amoeba (pronounced uh-MEE-buh) is any of several tiny, one-celled protozoa in the phylum (or primary division of the animal kingdom) Sarcodina. Amoebas live in freshwater and salt water, in soil, and as parasites in moist body parts of animals. They are composed of cytoplasm (cellular fluid) divided into two parts: a thin, clear, gel-like outer layer that acts as a membrane (ectoplasm); and an inner, more watery grainy

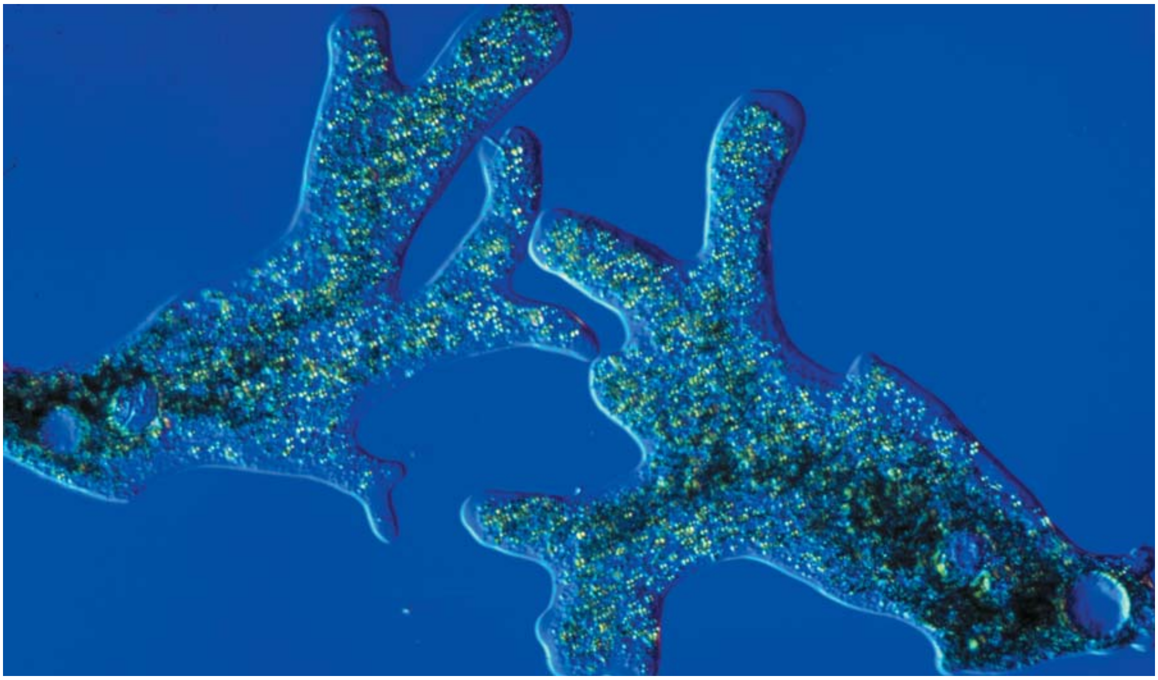
mass (endoplasm) containing structures called organelles. Amoebas may have one or more nuclei, depending upon the species.

The word amoeba comes from a Greek word meaning "to change." The amoeba moves by continually changing its body shape, forming extensions called pseudopods (false feet) into which its body then flows. The pseudopods also are used to surround and capture food—mainly bacteria, algae, and other protozoa—from the surrounding water. An opening in the membrane allows the food particles, along with drops of water, to enter the cell, where they are enclosed in bubblelike chambers called food vacuoles. There the food is digested by enzymes and absorbed into the cell. The food vacuoles then disappear. Liquid wastes are expelled through the membrane.

Water from the surrounding environment flows through the amoeba's ectoplasm by a process called osmosis. When too much water accumulates in the cell, the excess is enclosed in a structure called a contractile vacuole and squirted back out through the cell membrane. The membrane also allows oxygen to pass into the cell and carbon dioxide to pass out.

The amoeba usually reproduces asexually by a process called binary fission (splitting in two), in which the cytoplasm simply pinches in half

Amoeba proteus. (Reproduced by permission of Photo Researchers, Inc.)



Words to Know

Asexual reproduction: Any reproductive process that does not involve the union of two individuals in the exchange of genetic material.

Cytoplasm: The semifluid substance of a cell containing organelles and enclosed by the cell membrane.

Organelle: A functional structure within the cytoplasm of a cell, usually enclosed by its own membrane.

Osmosis: The movement of water across a semipermeable membrane from an area of its greater concentration to an area of its lesser concentration.

Protozoan: A single-celled, animal-like organism.

Pseudopod: From pseudo, meaning "false," and pod, meaning "foot"; a temporary extension from a cell used in movement and food capture.

and pulls apart to form two identical organisms (daughter cells). This occurs after the parent amoeba's genetic (hereditary) material, contained in the nucleus, is replicated and the nucleus divides (a process known as mitosis). Thus, the hereditary material is identical in the two daughter cells. If an amoeba is cut in two, the half that contains the nucleus can survive and form new cytoplasm. The half without a nucleus soon dies. This demonstrates the importance of the nucleus in reproduction.

Some amoebas protect their bodies by covering themselves with sand grains. Others secrete a hardened shell that forms around them that has a mouthlike opening through which they extend their pseudopods. Certain relatives of the amoeba have whiplike organs of locomotion called flagella instead of pseudopods. When water or food is scarce, some amoebas respond by rolling into a ball and secreting a protective body covering called a cyst membrane. They exist in cyst form until conditions are more favorable for survival outside.

Some common species of amoebas feed on decaying matter at the bottom of freshwater streams and stagnant ponds. The best-known of these, *Amoeba proteus,* is used for teaching and cell biology research. Parasitic species include *Entamoeba coli,* which resides harmlessly in human intestines, and *Entamoeba histolytica,* which is found in places where sanitation is poor and is carried by polluted water and sewage. Infection

with *Entamoeba histolytica* causes a serious intestinal disease called amoebic dysentery, marked by severe diarrhea, fever, and dehydration.

[*See also* **Cell; Protozoa; Reproduction**]

Amphibians

Amphibians are cold-blooded animals that possess backbones and display features that lie between those of fish and reptiles. They spend time both in water and on land. Their larvae (not yet fully developed offspring) mature in water and breathe through gills, like fish, while adults breathe air through lungs and skin. Amphibians are in the class Amphibia, which includes over 3,500 species. They are further divided into three orders: Anura (frogs and toads), Urodela (salamanders and newts), and Gymnophiona (caecilians, pronounced sih-SILL-yuhns, which are wormlike in appearance).

History

Amphibians evolved from fish about 400 million years ago, when the amount of dry land on Earth increased greatly. Certain fish adapted to these changing conditions by gradually developing limbs to crawl with and lungs to breathe with. Such organisms, capable of life both in water and on land, came to be called amphibians, a name that means "double life." Amphibians were the first vertebrates (animals with backbones) to live on land. However, they returned to the water to breed. The largest variety of amphibians occurred about 360 to 230 million years ago, when the environment was continually alternating between wet and dry conditions. Many of the species that developed during this period no longer exist. The groups of amphibians that survived to the present day can be traced back no further than 200 million years.

Characteristics

Amphibians are cold-blooded animals, meaning they do not have a constant body temperature but instead take on the temperature of their environment. They have moist, scaleless skin that absorbs water and oxygen, but that also makes them vulnerable to dehydration (loss of bodily fluids). Without moist conditions, their skin dries out and they die. Therefore, amphibians are most often found near ponds, marshlands, swamps, and other areas where freshwater is available. Some amphibians become

Words to Know

Estivation: State of inactivity during the hot, dry months of summer.

Gill: A bodily organ capable of obtaining oxygen from water.

Hibernation: State of rest or inactivity during the cold winter months.

Invertebrate: An animal lacking a spinal column.

Larva: An animal in its early form that does not resemble the parent and must go through metamorphosis, or change, to reach its adult stage.

Vertebrate: An animal having a spinal column.

inactive when conditions are unfavorable for survival. This period of inactivity is called estivation when it occurs during hot, dry weather and hibernation when it occurs in response to cold temperatures. Activity resumes when favorable conditions return.

The thin skin of amphibians contains many glands, among them poison glands that protect certain species against predators. The poison from the glands of the brightly colored poison-dart frog is particularly toxic and is used by South American Indians to coat the tips of their arrows. Some amphibians protect themselves from enemies by changing color to blend in with their surroundings.

Life cycle

The life cycle of most amphibians begins in water when the female lays eggs that are fertilized outside of her body. The eggs then hatch into larvae, or tadpoles, that breathe through external gills. The larvae grow flat tails and feed on vegetation. During a process called metamorphosis, physical changes occur and external gills give way to lungs. The tadpoles also change from plant-eating animals to meat eaters. Amphibians usually reach full adulthood at three to four years.

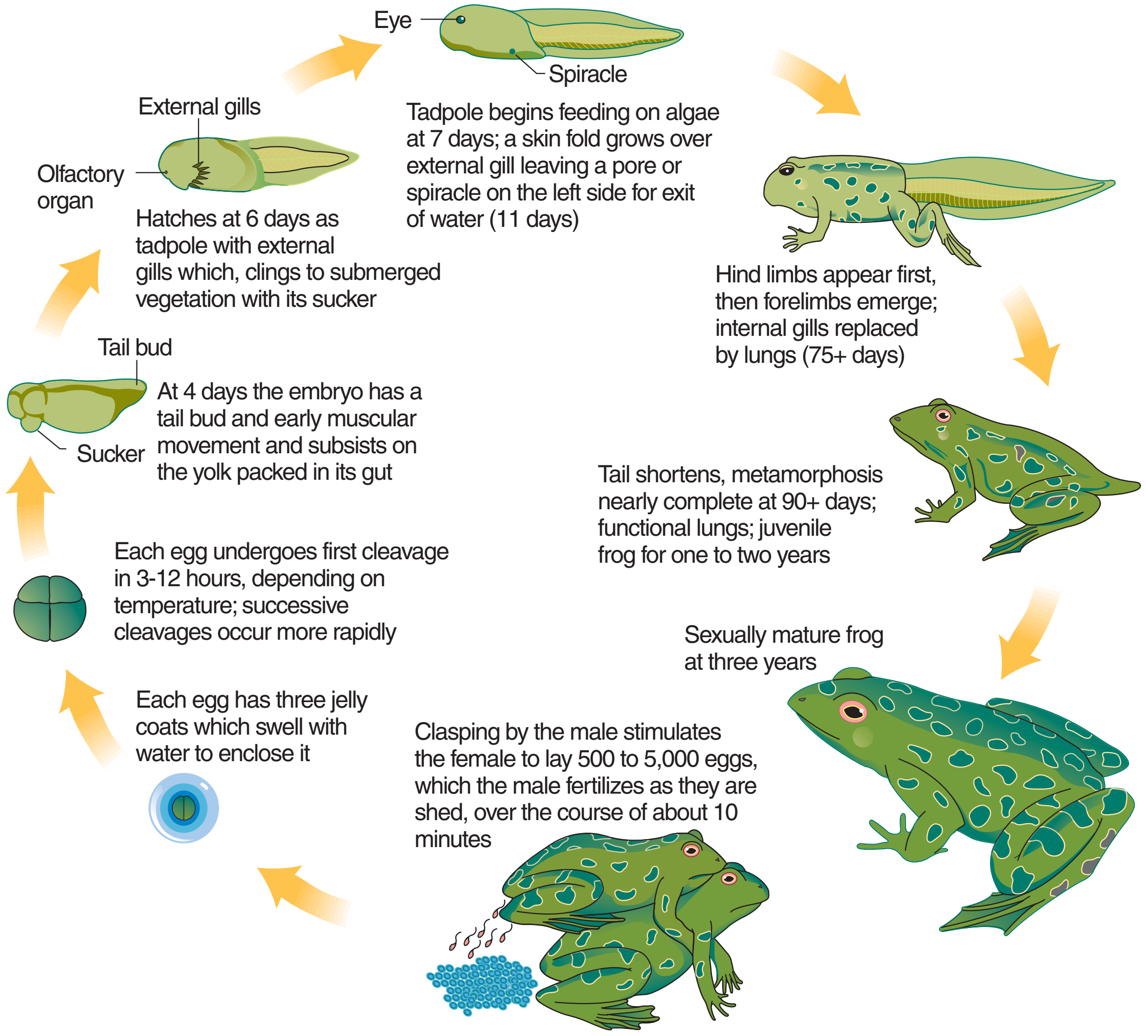
Not all amphibians follow this pattern of reproduction. Some salamanders live out their entire lives on land, where they give birth to fully formed live young. Others lay their eggs in moist places on the forest floor, where they hatch as tiny versions of the adults. Some newts retain

their external gills throughout their lives. The red-spotted newt of eastern North American spends its juvenile stage on land as the red eft, returning to water to develop and live as an adult.

Three major groupings

Anurans. Frogs and toads make up the order Anura, the largest group of living amphibians, comprising about 3,000 species. Anurans lack tails and have long hind legs that are well adapted for jumping and swimming. Most anurans live in areas where there is freshwater, although some are well adapted to drier habitats. Some common anurans of North America

The life cycle of frogs. *(Reproduced by permission of The Gale Group.)*



include the bullfrog, spring peeper, American toad, and spadefoot toad. Frogs and toads differ in that toads have shorter legs and drier skin that appears warty in comparison to the smooth skin of frogs. Frogs range in size, the smallest measuring about 1 inch (2.5 centimeters) and the largest (the West African Goliath frog)measuring more than 1 foot (about 30 centimeters).

Frogs and toads live mainly on a diet of insects and other invertebrates. The largest frogs and toads also eat small mammals, birds, fish, and other amphibians.

Urodeles. The order Urodela contains about 250 species of newts and salamanders. Urodeles range in size from approximately 4 inches (about 10 centimeters) to the largest of all amphibians, the giant salamander of Japan, which grows to more than 5 feet (about 1.5 meters). Urodeles have long tails and small, underdeveloped legs. They are usually found in or near water and often reside in moist soil under rocks or logs. Adults usually spend most of their time on land and have a diet consisting of insects and worms.

Some species of urodeles are aquatic (live in water), including those of the genus *Siren.* These North American amphibians are shaped like eels, have small forelegs and no hind legs or pelvis. They breathe through external gills as well as lungs and burrow in mud at the bottom of marshes.

Gymnophions. Caecilians of the order Gymnophiona are blind, legless amphibians shaped like worms. They burrow in moist soil in tropical habitats of Africa and South America, feeding on soil invertebrates such as worms. There are at least 160 species of caecilians, ranging in size from 4 inches (about 10 centimeters) to 4.5 feet (about 1 meter) in length, but most are rarely seen despite their size.

Recent decline

In the last half of the twentieth century, scientists noted the alarming decline in the numbers of amphibians and amphibians species around the world. They theorized the decline was due to a number of factors: pollution of freshwater ecosystems, the destruction of amphibian habitats by ever-spreading human populations, and, possibly, increased ultraviolet radiation due to ozone depletion. Amphibians are known as indicator species, or species whose health is an indicator or sign of the health of the ecosystem they inhabit. As their numbers decrease, so do the number of healthy ecosystems around the world, which in turn results in the loss of many other animal and plant species.

Anatomy

Anatomy is a branch of biology that deals with the structure of plants and animals. Comparative anatomy is a related field in which the structures of different animals are studied and compared. There are three main areas of anatomy: gross anatomy deals with organs and organ groupings called systems that are visible to the naked eye; cytology is the study of cell structure; and histology examines the structure of tissues. Microscopes are used in both cytology and histology to study cell and tissue structures.

History of anatomy

Attempts to understand the structure of living things go as far back as Aristotle (384–322 B.C.), the famous Greek philosopher and biologist. His dissection (cutting into pieces to examine the parts) and study of animals and plants led to his formation of a classification system that was used by scientists for almost 2,000 years.

Some of the first human dissections were carried out by Greek anatomists and physicians Herophilus (late fourth century B.C.) and his younger follower Erasistratus. Herophilus made many anatomical studies of the brain. He distinguished the cerebrum (larger portion) from the cerebellum (smaller portion), suggested that the brain was the seat of intelligence, and identified and named several structures of the brain, some of which still carry the names he gave them. He also discovered that nerves originate in the brain and noted the difference between motor nerves (those concerned with motion) and sensory nerves (those related to sensation). Together with Erasistratus, Herophilus established the disciplines of anatomy and physiology (the science that deals with the function of the body's parts and organs).

In his studies of the heart and blood vessels, Erasistratus came very close to working out the circulatory system of the blood. He understood that the heart served as a pump and he studied and explained the function of the heart valves. Erasistratus theorized that the arteries and veins both spread from the heart but incorrectly believed that the arteries carried air instead of blood.

After Erasistratus's time, the dissection of human bodies to study their anatomy ended due to the pressure of public opinion. Egyptians believed that a body needed to remain whole to enter the afterlife, and they engaged in the practice of mummification (treating a body with preservatives for burial).

Important contributions to the science of anatomy were made by the last and most influential of the great ancient medical practitioners,

Greek physician Claudius Galen (A.D. 131–200). He expertly dissected and accurately observed all kinds of animals but sometimes mistakenly applied what he saw to the human body. Nevertheless, he was the first to observe that muscles work in opposing pairs: for every muscle that causes a joint to bend, there is an opposing muscle that restores the joint to its original position.

Through experiments, Galen observed and described two ground-breaking anatomical events: (1) paralysis resulting from the cutting of the spinal cord and (2) the process by which urine passes from the kidneys to the bladder. In his observations about the heart and blood vessels, however, Galen made critical errors that remained virtually unchallenged for 1,400 years. He mistakenly believed that blood was formed in the liver and was circulated throughout the body by the veins. When anatomical research stopped for many centuries, Galen's teachings remained the ultimate medical authority.

After human dissections resumed in the sixteenth century, the long-held teachings of Galen were overturned by the work of Flemish anatomist and physician Andreas Vesalius (1514–1564). Vesalius, who founded modern scientific anatomy, noted obvious conflicts between what he saw in his dissections of the human body and what Galen had described. He reasoned that Galen's errors resulted from only having done animal dissections, which often did not apply to human anatomy.

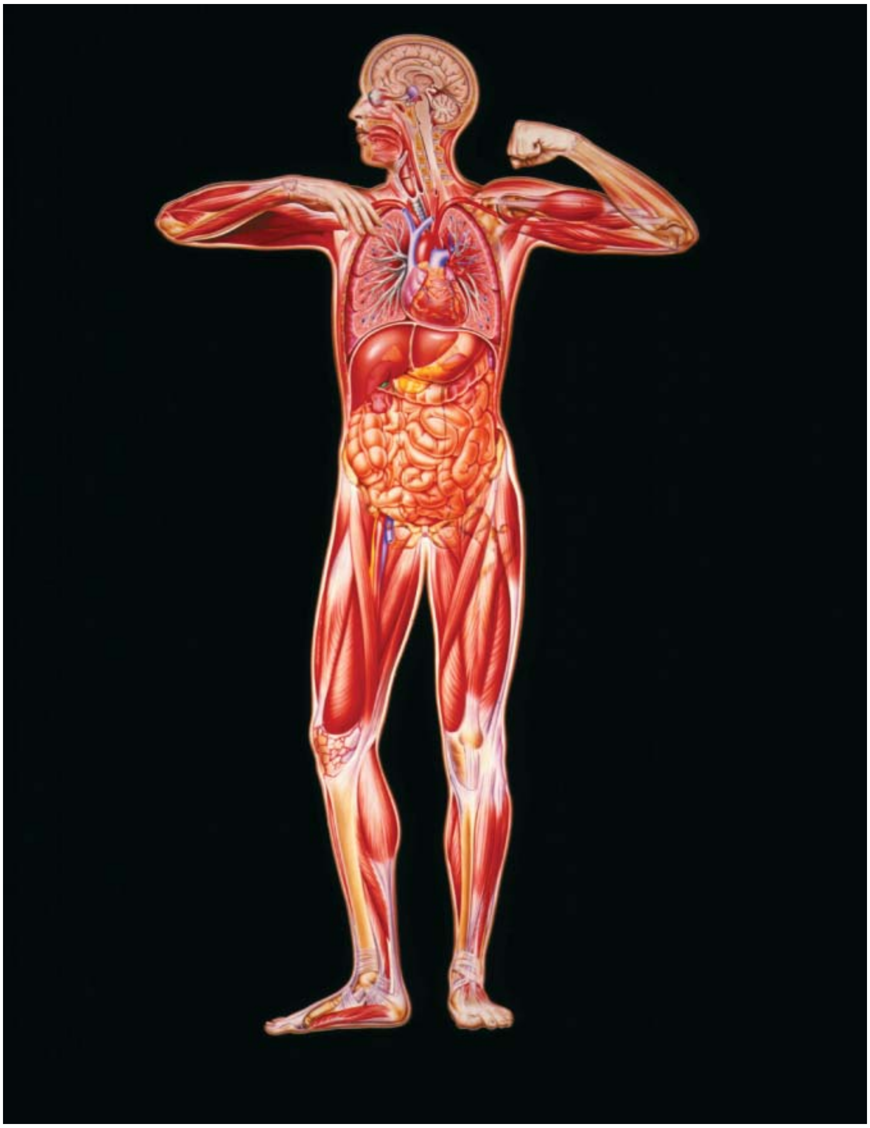
In 1543, Vesalius published one of the most important books in medical history and the world's first textbook of anatomy, *On the Structure of the Human Body.* The book contains detailed anatomical descriptions of all parts of the human body, directions for carrying out dissections, and meticulously drawn illustrations. Vesalius believed that accurate, basic knowledge of the human body could only be gained by performing human dissections. In his book, he set forth an objective, scientific method of conducting medical research that was to become the foundation of anatomical research and education throughout the world.

The correct description of the circulation of blood was provided by English physician William Harvey (1578–1657). In the course of many experimental dissections, he established the existence of pulmonary circulation (blood flowing from heart to lungs to heart) and noted the one-way flow of blood. He was the first to discover that blood flows in a continuous circle from the heart to the arteries to the veins and back to the heart. Harvey published this radical new concept of blood circulation in 1628.

The discovery of capillaries (small blood vessels) by Italian anatomist Marcello Malpighi (1628–1694) in 1661 provided the factual evidence to confirm Harvey's theory of blood circulation. Malpighi dis-

covered the capillaries—the tiny connecting links between the veins and arteries—using the newly invented microscope.

The science of anatomy was further advanced by the work of English physicist Robert Hooke (1635–1703). His 1665 publication *Micrographia* describes the structures of insects, fossils, and plants in detail from his microscopic studies. While examining the porous structure of cork, Hooke coined the term "cells" to describe the tiny rectangular holes he observed. This led scientists to adopt the concept of cells as the unit



This diagram shows the many different layers of human body anatomy, from bone to muscle, organs, and, finally, skin. *(Reproduced by permission of Photo Researchers, Inc.)*

structures of tissues, which in turn led to the suggestion of cells as the building blocks of organs and to the discovery of the cell nucleus. A later theory proposing that all of the body's tissues are composed of cells was the basis for the science of cytology.

Histology, or the study of tissues (structured groups of specialized cells), began in earnest in the 1700s with the work of French scientist Xavier Bichat (1771–1802). Bichat found that organs were built up out of different types of simpler structures, and each of these simpler structures could occur in more than one organ. He further noted that different tissues have specific properties and are thereby vulnerable to tissue-specific diseases.

Until that time, general anatomy was a descriptive order, based upon obvious characteristics such as the location of organs. Bichat suggested adopting a systematic order for anatomy based upon structure and function. He specified 21 tissues (or systems) in the human body based on what he saw with his naked eye, distinguishing these different tissues by their composition and by the arrangement of their fibers. These include epithelial (skin and digestive), muscular, nervous, connective, and vascular (blood) types.

Histology began to take on its modern form with the introduction of cell theory in 1839. At that time tissues began to be understood not as the basic building blocks of living things but as unique systems of cells with their own stages of development within the embryo (early stage of an organism's growth before birth or hatching).

Modern anatomy

Anatomy today makes use of knowledge from many fields of science to explore and understand how the structure of an organism's cells, tissues, and organs relates to their function.

Human anatomy, a crucial element in the medical school curriculum, divides the body into separate functional systems. These consist of the skin, the muscles, the skeleton, the circulatory system (blood, blood vessels, and heart), the digestive system, the urinary system, the respiratory system (lungs and breathing), the nervous system (brain, spinal cord, and nerves), the endocrine system (glands and hormones), and the reproductive system.

[*See also* **Circulatory system; Digestive system; Endocrine system; Muscular system; Nervous system; Reproductive system; Respiratory system; Skeletal system**]

Anesthesia

Anesthesia is the term given to the loss of feeling or sensation. In medical terms, it is the method of decreasing sensitivity to pain in a patient so that a medical procedure may be performed. Anesthesia may be accomplished without the loss of consciousness, or with partial or total loss of consciousness.

There are two kinds of anesthesia: general anesthesia, which affects the entire body and causes a loss of consciousness, and local anesthesia, in which only the area being operated on is affected. With local anesthesia, the patient may be conscious during the course of the operation or given a sedative, a drug that induces drowsiness or sleep.

Anesthesiology is the branch of medicine dealing with anesthesia and anesthetics. Anesthetics can be administered by doctors (called anesthesiologists) or by specially trained nurses (called CRNAs, certified registered nurse anesthetists) working under a doctor's guidance. The development of modern anesthesia has made possible complex operations such as open heart surgery.

History of anesthesia

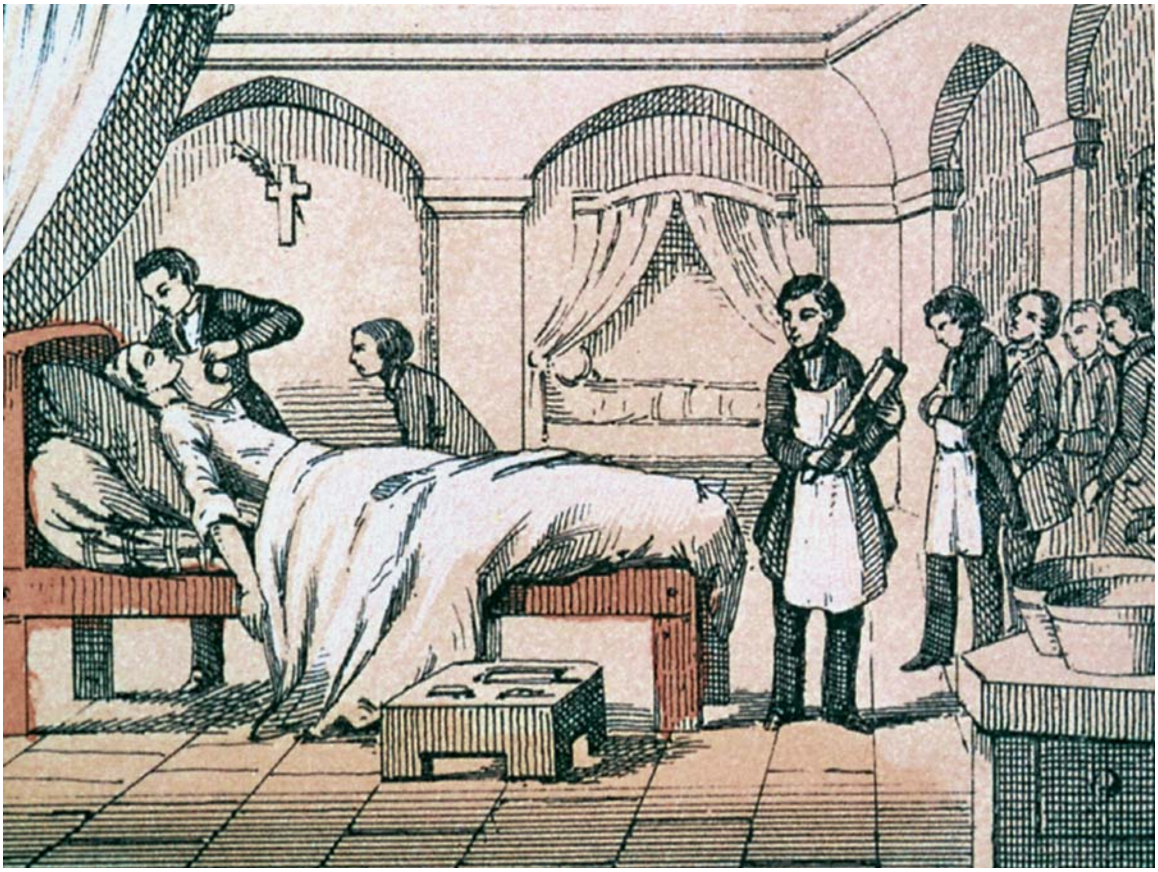
Methods for lessening the sensation of pain during surgery date back to ancient times. Before the discovery of substances that produced general anesthesia, patients needing surgery for illness or injury had to rely on alcohol, opium (a natural narcotic derived from the opium poppy), or fumes from an anesthetic-soaked cloth to deaden the pain of the surgeon's knife. Often a group of men held the patient down during an operation in case the opium or alcohol wore off. Under these conditions, many patients died of shock from the pain of the operation itself.

Nitrous oxide, ether, and chloroform. The gases nitrous oxide, ether, and chloroform were first used as anesthetics in the nineteenth century, ushering in the modern era of anesthesia. Nitrous oxide, or laughing gas, was discovered as an anesthetic by English chemist Humphry Davy (1791–1867) in 1799. Davy's finding was ignored until the next century, when Connecticut dentist Horace Wells (1815–1848) began to experiment using nitrous oxide as an anesthetic during tooth surgery. In 1845, he attempted to demonstrate its pain-blocking qualities to a public audience but was unsuccessful when he began to pull a tooth before the patient was fully anesthetized. The patient cried out in pain and, as a result, another 20 years passed before nitrous oxide was accepted for use as an anesthetic.

The first use of ether as an anesthetic during an operation was claimed by surgeon Crawford W. Long (1815–1878) of Georgia in 1842. The operation, however, was unrecorded, so official credit went instead to Massachusetts dentist William Morton (1819–1868) for his 1846 public demonstration of an operation using ether performed in a Boston hospital. While Morton administered the gas to the patient through an inhaling device, John C. Warren (1778–1856) removed a neck tumor without the patient feeling any pain. Following this landmark use of ether as an anesthetic, general anesthesia began to be practiced all over the United States and Europe.

Chloroform was introduced as a surgical anesthetic by Scottish obstetrician James Young Simpson (1811–1870) in 1847. After first experimenting with ether, Simpson searched for an anesthetic that would make childbirth less painful for women. Although it eased the pain of labor, chloroform had higher risks than those associated with ether. Neither ether nor chloroform are used in surgery today.

A nineteenth-century physician administering chloroform prior to surgery. Ether was one of the earliest anesthetics to be used but it was difficult to administer as it usually made the patient choke. *(Reproduced by permission of Photo Researchers, Inc.)*



Emergence of anesthesiology

Anesthesiology was slow to develop as a medical specialty. By the end of the nineteenth century, ether—which was considered safer than chloroform—was administered by persons with little medical experience. Nurses were eventually assigned to this task, becoming the first anesthetists at the turn of the century.

As surgical techniques progressed in the twentieth century, there was a corresponding demand for specialists in the area of anesthesia. To meet this need, the American Society of Anesthetists was formed in 1931, followed by the American Board of Anesthesiology in 1937, which certified anesthetists as specialists. In the next 50 years, over 13,000 physicians and nurses were certified as specialists in the field of anesthesiology.

Types of anesthesia

Modern anesthesia uses both chemical agents and nondrug methods as preparation for medical procedures. Chemical agents are drugs that can be administered by mouth, by injection into muscle or under the skin with a needle, intravenously (by needle into a vein), or with a gas mask for inhalation. They also come in forms such as creams, gels, or liquids that can be applied or sprayed directly onto the area being treated. Nondrug methods include acupuncture (the insertion of fine needles into the body to relieve pain) and the Lamaze method of natural childbirth, which involves breathing, focusing, and relaxation techniques to limit pain during labor and delivery.

General anesthesia. General anesthesia consists of placing the patient in an initial state of unconsciousness, keeping the patient unconscious while surgery is being performed, and bringing the patient back to consciousness after the surgery is over.

A drug commonly used to bring about unconsciousness is thiopentone sodium, a drug that acts within 30 seconds after being injected intravenously. The unconscious state is then maintained with other drugs. Inhaled anesthetics (gases or liquids that change readily into gases) are also used to bring about and maintain unconsciousness. These include nitrous oxide, halothane, enflurane, and isoflurane. A combination of barbiturates, nitrous oxide, narcotics (drugs that cause sleep and relieve pain), and muscle relaxants is often used throughout the course of an operation. This is usually safer than giving a very large dose of a single drug that can have serious side effects.

During surgery, the anesthesiologist or anesthetist keeps a constant watch on the patient's blood pressure, breathing, and heartbeat, and adjusts the levels of anesthetics being administered as necessary.

Local anesthesia. Local anesthesia is accomplished using drugs that temporarily block the sensation of pain in a certain area of the body while the patient remains awake. These drugs act by preventing nerve cells from sending pain messages to the brain. Some local anesthetics are benzocaine, lidocaine, and procaine (Novocain). They are used in dental and surgical procedures, medical examinations, and for relieving minor symptoms such as itching or the pain of toothaches or hemorrhoids. Spinal anesthesia, sometimes called a saddleblock, is achieved by injecting anesthetics with a fine needle into the spine, which numbs the abdomen, lower back and legs. It is sometimes used in such procedures as childbirth and hip and knee surgery.

Animal

Animals are creatures in the kingdom Animalia, one of the five major divisions of organisms. They are multicelled, eukaryotic (pronounced yoo-kar-ee-AH-tik) organisms, meaning their cells contain nuclei and other structures called organelles, all of which are enclosed by thin membranes. (Eukaryote means "true nucleus.") Unlike plants, their cells do not have cell walls. Animals are capable of moving their bodies, often in response to what they sense in their environment. For food, animals ingest plants and other organisms. The scientific study of animals is called zoology.

Animals have existed for millions of years, but it is not known when they first appeared on Earth. The earliest animals were soft-bodied, multicellular life-forms that did not preserve well as fossils. (A fossil is the remains or print of an organism from long ago that has been preserved in rock.) By the time animal parts became hardened in rock about 640 to 670 million years ago, numerous well-developed multicellular animals already existed. Therefore, the beginnings of the animal kingdom must have occurred earlier.

Most zoologists recognize the existence of 30 to 35 phyla (related groups) of animals, some of which are extinct (no longer exist) and are known only from their fossil record. Animals that live today come in many forms and sizes, the very smallest visible only under a microscope and the very largest, the blue whale, reaching 100 feet (30 meters) in length and weighing up to 300,000 pounds (136,000 kilograms). Animals are classified as vertebrates (having backbones) or invertebrates (without backbones).

Among the most primitive of the animals are the sponges, invertebrates that live in water. Sponges have no nerve cells or muscles. They

are shaped like vases, with water flowing in through holes in their sides and leaving through an opening in their top. Sponges are remarkable for their ability to regenerate. Although many invertebrates are capable of growing new body parts, sponges are capable of growing into a new individual from even the tiniest fragment of the original body. It is believed that although sponges have lived successfully for about one billion years, yet it seems that they did not give rise to any other animal forms.

Some of the simplest animals with the oldest ancestral lines are invertebrates such as jellyfish, sea anemones (pronounced uh-NEH-muh-neez), and corals, which also live in water. They have radial body symmetry, which means that their bodies are arranged equally around a central point. This arrangement allows them to sense food and danger approaching from all directions. The simplest animals having bilateral symmetry (meaning that both the left and right sides of their bodies are mirror images of each other) include the invertebrate flatworms and roundworms. These animals live in water, on land, and as parasites in the body fluids of other organisms. Bilateral symmetry was an important evolutionary development because it allowed for forward movement of animals. It also is associated with the development of separate head and tail areas, as well as a distinction between the upper and under portions of an animal's body.

The black bear, one of the most recognizable animals in America, at a Minnesota campsite. *(Reproduced by permission of the U.S. Fish and Wildlife Service.)*

Words to Know

Bilateral symmetry: Two-sided symmetry where the left and right sides of the body are identical, with each side containing similar structures.

Coelom: The cavity between the body wall and gut that is lined with specialized cells and that serves to protect the organs within.

Eukaryote: Multicellular organism whose cells contain true nuclei and membrane-bound structures called organelles.

Radial symmetry: Identical or similar body shape around one central point so that any line drawn through the center yields similar right and left halves.

Another major step in the evolution of animals was the development of a body cavity called the coelom (pronounced SEE-luhm). The coelom is a cavity in the body between the gut and the body wall that houses the internal organs, such as the liver, stomach, and heart. Animal groups that have coeloms include Mollusca (snails, clams, octopus, and squid), Annelida (earthworms and leeches), Arthropoda (insects, spiders, and crabs), Echinodermata (sea urchins and starfish), and Chordata (fish, amphibians, reptiles, birds, and mammals). All of the vertebrates are included in the group Chordata.

About one million species of animals have been named. However, biologists estimate that a much larger number of animal species has yet to be discovered; the actual total could be as large as 30 to 50 million species.

[*See also* **Arthropods; Mollusks**]

Antarctica

Antarctica, lying at the southernmost tip of the world, is the coldest, driest, and windiest continent. Ice covers 98 percent of the land, and its 5,100,000 square miles (13,209,000 square kilometers) cover nearly one-tenth of Earth's land surface, about the same size as Europe and the United States combined. Despite its barren appearance, Antarctica and its

surrounding waters and islands teem with life, and the continent plays a significant role in the climate and health of the entire planet.

Although humans have never settled on Antarctica because of its brutal climate, since its discovery in the early 1800s explorers and scientists have traveled across dangerous seas to study the continent's winds, temperatures, rocks, wildlife, and ice. While some countries have tried to claim parts of the continent as their own, Antarctica is an independent

Antarctica. *(Reproduced by permission of The Gale Group.)*

continent protected by international treaty from ownership by any one country.

Overview

Archaeologists and geologists believe that millions of years ago Antarctica was part of a larger continent called Gondwanaland. About 200 million years ago, as a result of shifting in the plates of Earth's crust, Gondwanaland broke apart and created the separate continents of Antarctica, Africa, Australia, South America, and India. Antarctica is currently centered roughly on the geographic South Pole, the point where all south latitudinal lines meet. It is the most isolated continent on Earth, 600 miles (1,000 kilometers) from the southernmost tip of South America and more than 1,550 miles (2,500 kilometers) away from Australia.

Seventy percent of Earth's freshwater is frozen atop the continent. These icecaps reflect warmth from the Sun back into the atmosphere, preventing the planet from overheating. Huge icebergs break away from the stationary ice and flow north to mix with warm water from the equator, producing currents, clouds, and complex weather patterns. Creatures as small as microscopic phytoplankton and as large as whales live on and around the continent, including more than 40 species of birds.

Geology. Almost all of Antarctica is under ice, in some areas by as much as 2 miles (3 kilometers). The ice has an average thickness of about 6,600 feet (2,000 meters), which is higher than most mountains in warmer countries. This grand accumulation of ice makes Antarctica the highest continent on Earth, with an average elevation of 7,500 feet (2,286 meters). If all of this ice were to melt, global sea levels would rise by about 200 feet (65 meters), flooding the world's major coastal ports and vast areas of low-lying land.

Under the ice, the Antarctic continent is made up of mountains. The Transantarctic Mountains are the longest range on the continent, stretching 3,000 miles (4,828 kilometers) from the Ross to Weddell Seas. Vinson Massif, at 16,859 feet (5,140 meters), is the highest mountain peak. The few areas where mountains peak through the ice are called nunataks.

Around several parts of the continent, ice forms vast floating shelves. The largest, known as the Ross Ice Shelf, is about the same size as Texas or Spain. Since the shelves are fed by glaciers on the continent, the resulting shelves and icebergs are made up of frozen freshwater. The largest glacier on Earth, the Lambert Glacier on the eastern half of the continent, is 25 miles (40 kilometers) wide and more than 248 miles (400 kilometers) long.

Gigantic icebergs are a unique feature of Antarctic waters. They are created when huge chunks of ice separate from an ice shelf, a cliff, or a glacier, a process known as calving. Icebergs can be amazingly huge; an iceberg measured in 1956 was 208 miles (335 kilometers) long by 60 miles (97 kilometers) wide, and was estimated to contain enough freshwater to supply the water needs of London, England, for 700 years. Only 10 to 15 percent of an iceberg normally appears above the water's surface. As these icebergs break away from the continent, new ice is added to the continent by snowfall.

Icebergs generally flow northward and, if they don't become trapped in a bay or inlet, will reach the Antarctic convergence, the point in the ocean where cold Antarctic waters meet warmer waters. At this point, ocean currents usually sweep the icebergs from west to east until they melt. An average iceberg will last several years before melting.

Climate. Antarctica is the windiest and coldest place on Earth. The wind can gust up to 200 miles per hour, or twice as hard as the average hurricane. Little snow actually falls in Antarctica; because the air is so cold, what snow that does fall turns immediately to ice. In winter, temperatures may fall to −100°F (−73°C). The world's record for lowest temperature was recorded on Antarctica in 1960, when it fell to −126.9°F (−89.8°C).

Strong winds constantly travel over the continent as cold air races over the high ice caps and then flows down to the coastal regions. Winds associated with Antarctica blizzards commonly gust to more than 120 miles (193 kilometers) per hour, and are among the strongest winds on Earth. Even at its calmest, the continent's winds can average 50 to 90 miles (80 to 145 kilometers) per hour.

Even with all its ice and snow, Antarctica is the driest continent on Earth based on annual precipitation amounts. The constantly cold temperatures have allowed each year's annual snowfall to build up without melting over the centuries. Along the polar ice cap, annual snowfall is only 1 to 2 inches (2.5 to 5 centimeters). More precipitation falls along the coast and in the coastal mountains, where it may snow 10 to 20 inches (25 to 51 centimeters) per year.

Plants and animals. The Antarctic continent is nearly barren due to the persistently cold and dry climate. Hardy plants like pearlwort (a flowering plant), mosses, and lichen (a combination of algae and fungi) are found along the coast and on the Antarctic Peninsula, the warmest part of the continent.

Few creatures can survive Antarctica's brutal climate. Life in the sea and along the coast of Antarctica and its islands, however, is often abun-

Words to Know

Antarctic Circle: The line of latitude at 66°32'S, where there are 24 hours of daylight in midsummer and 24 hours of darkness in midwinter.

Antarctic convergence: 25-mile (40-kilometer) region where cold Antarctic surface water meets warmer water and sinks below it.

Antarctic Ocean: The seas surrounding the continent, where the Atlantic, Pacific, and Indian Oceans converge.

Calving: When huge chunks of ice or icebergs break off from ice shelves and sheets.

Glacier: A river of ice that moves down a valley to the sea, where it breaks into icebergs.

Nunataks: Mountain peaks that thrust through the ice and snow cover.

South Pole: The geographically southernmost place on Earth.

dant. Several seabirds make the Antarctic their home, including 24 species of petrels, small seabirds that dart over the water and nest in rocks along the shore. A wide variety of animals make the surrounding waters their home, from zooplankton (small floating organisms) to seals and whales.

Of all the animals, penguins are the primary inhabitants of Antarctica. Believed to have evolved 40 to 50 million years ago, they have oily feathers that provide a waterproof coat and a thick layer of fat for insulation. Penguins' bones are solid, not hollow as are those of most flying birds. Solid bones add weight, making it easier for penguins to dive into the water for food. These bones also prevent them from flying, but because they do not have predators that can live in the brutally cold climate, they do not need to fly. Thus their wings have evolved over the centuries to resemble flippers or paddles.

Exploration of the continent

Greek philosopher Aristotle hypothesized more than 2,000 years ago that Earth was round and that the Southern Hemisphere must have a landmass large enough to balance the lands in the Northern Hemisphere. He called the proposed land mass *Antarktikos,* meaning the opposite of the Arctic.

The continent remained a mystery until English navigator and explorer James Cook crossed the Antarctic Circle and sailed around the continent in 1773. While he stated that the land was uninhabitable because of the ice fields surrounding the continent, he noted that the Antarctic Ocean was rich in whales and seals. For the next 100 years, hunters exploited this region for the fur and oil trade, traveling ever farther and farther south.

In 1895, the first landing on the continent was accomplished by the Norwegian whaling ship *Antarctic*. The British were the first to spend a winter on Antarctica, in 1899. By 1911, a race had begun to see who would first reach the South Pole, an imaginary geographical center point at the bottom of Earth. Again, a Norwegian, Roald Amundsen, was the first to reach it, on December 14, 1911.

Scientific exploration

The International Geophysical Year (IGY), from July 1, 1957, to December 31, 1958, was a planned cooperative venture by scientists from 56 nations to study a variety of subjects. During this venture, 12 nations conducted research in Antarctica, setting up base camps in various locations, some of which are still used today. Topics of research included

A glacier system in Antarctica. *(Reproduced by permission of JLM Visuals.)*

the pull of gravity, cosmic rays, the southern lights, and changes in the atmosphere.

Since these cooperative research projects, several agreements have been signed to ensure that political conflicts do not arise concerning research and use of Antarctica. The Antarctic Treaty was signed on December 1, 1959, by the 12 nations involved in the IGY projects, and made official on June 23, 1961, after each country ratified it within their own governments. As of April 1994, 42 countries had committed themselves to the spirit of cooperation outlined in the treaty, making it one of the most successful international agreements ever created.

The treaty requires all countries to give up any territorial claims, to exchange scientific investigations and results, and to stop all military activity and weapons testing (including nuclear testing and the disposal of radioactive wastes) in the region. Any disputes that cannot be settled by negotiation or arbitration are sent to the International Court of Justice for settlement. The treaty thus sets aside 10 percent of Earth as a nuclear-free, demilitarized zone.

In 1991, the countries added the Protocol on Environmental Protection to the treaty. The Protocol grew out of concerns that poor habits by researchers and increasing numbers of tourists were increasing pollution problems on the continent. It requires countries to protect the continent's ecosystem (its community of plants and animals), paying particular attention to the production and disposal of wastes.

Current events

A wide variety of research is continuing on Antarctica. Astronomer's find the continent's cold temperatures and high altitude allow for a clearer view of the stars and planets. Antarctica is also the best place to study interactions between solar wind and Earth's magnetic field, temperature circulation in the oceans, unique animal life, ozone depletion, ice zone ecosystems, and glacial history. Buried deep in Antarctica ice lie clues to ancient climates, which may provide answers to whether Earth is due for global warming or the next ice age.

[*See also* **Greenhouse effect; Ozone; Plate tectonics**]

Antenna

An antenna is a device used to transmit and receive electromagnetic waves, such as radio waves and microwaves. Antennas are found in a

great variety of communication devices, including radios and television sets, weather radar systems, satellite communications systems, and radio astronomy research centers.

Your local radio station uses an antenna to transmit the programs it broadcasts. Words that are spoken or music that is played within the station are converted to electrical signals. These signals are then transmitted to an antenna in the form of an electric current. Electrons inside the antenna vibrate back and forth with the same frequency as the incoming

The antenna for a Doppler weather radar site. Doppler radar can be used to detect various weather conditions. *(Reproduced by permission of The Stock Market.)*

electric current. The vibration is characteristic of the sounds produced within the station. As these electrons vibrate, they create an electromagnetic wave in the air around the antenna. That wave spreads out and travels in all directions from the antenna. The frequency of the wave is the same as the frequency of the electron vibration in the antenna and of the sounds spoken in the station.

An antenna placed in the path of these waves reverses the above process. Electromagnetic waves in the air cause electrons in the receiving antenna to begin vibrating. The frequency of vibration is the same in the receiving antenna as it is in the wave. The vibrating electrons are converted into an electrical current, which travels into your radio receiver and is converted back into sound.

Antennas come in all sizes and shapes, from the tiny units found in miniature transistor radios to the massive structures used to transmit messages to and receive messages from outer space.

[*See also* **Microwave communication; Radar; Radio**]

Antibiotics

The discovery of antibiotics greatly improved the quality of human life in the twentieth century. Antibiotics are drugs such as penicillin (pronounced pen-ih-SILL-in) and streptomycin (pronounced strep-toe-MY-sin) used to fight infections and infectious diseases caused by bacteria. Antibiotic drugs are made from living organisms such as fungi, molds, and certain soil bacteria that are harmful to disease-causing bacteria. Antibiotics can also be produced synthetically (artificially) or combined with natural substances to form semisynthetic antibiotics. These compounds work against strains of bacteria that are resistant to other antibiotics.

Some microscopic bacteria that enter the human body through an opening or a wound find abundant food and reproduce quickly in great numbers, releasing toxins (poisons) as they grow or when they die. The toxins can destroy human cells or interfere with cell function, causing diseases like pneumonia or tuberculosis. Antibiotics fight bacteria either by killing them or by preventing them from multiplying. (Indeed, the word antibiotic comes from *anti-,* meaning "against," and *bios,* meaning "life.") It is believed that antibiotics accomplish these actions by damaging bacterial cell walls or by otherwise interfering with the function of the cells.

Words to Know

Antibacterial: Working against bacteria either by destroying it or keeping it from multiplying.

Antibiotic resistance: The ability of bacteria to resist the actions of antibiotic drugs.

Soil bacteria: Bacteria found in the soil that destroy other bacteria.

History of antibiotics

Sulfa drugs. Sulfa drugs, originally developed for use in the dye industry, were the first effective drugs used to fight bacterial infection in humans. Prontosil, the first sulfa drug, was discovered in 1935 by German chemist Gerhard Domagk (1895–1964). Also called sulfonamides (pronounced sul-FOHN-uh-midze), these drugs are synthesized (made) in the laboratory from a crystalline compound called sulfanilamide (pronounced sul-fuh-NILL-uh-mide). They work by blocking the growth and multiplication of bacteria and were initially effective against a broad range of bacteria. However, many strains of bacteria have developed a resistance to sulfa drugs. Resistance occurs when some bacteria survive attack by the antibacterial drug and change in such a way that they are no longer affected by the drug's action.

Sulfa drugs are most commonly used today in the treatment of urinary tract infections. The drugs are usually taken by mouth, but other forms include creams that can be applied to burn wounds to prevent infection and ointments and drops used for eye infections.

Development of penicillin as an antibiotic. In 1928, British bacteriologist Alexander Fleming (1881–1955) discovered the bacteria-killing property of penicillin. Fleming noticed that a mold that had accidentally fallen into a bacterial culture in his laboratory had killed the bacteria. Having identified the mold as the fungus *Penicillium notatum,* Fleming made a juice with it that he named penicillin. After giving it to laboratory mice, he discovered it killed bacteria in the mice without harming healthy body cells. Although Fleming had made an incredible discovery, he was unable to produce penicillin in a form useful to doctors.

It was not until 1941 that two English scientists, Howard Florey (1898–1968) and Ernst Chain (1906–1979), developed a form of penicillin that could be used to fight bacterial infections in humans. By 1945, penicillin was available for widespread use and was hailed as the new wonder drug. The antibiotic works by blocking the formation of the bacterial cell wall, thus killing the bacteria. It is still used successfully in the treatment of many bacterial diseases, including strep throat, syphilis (a sexually transmitted disease) and pneumonia. Fleming, Florey, and Chain shared the 1945 Nobel Prize for medicine for their work on penicillin.

The search for other antibiotics

Despite the effectiveness of penicillin, it was soon found that the drug worked against only certain types of bacteria. In 1943, American microbiologist Selman Waksman (1888–1973) developed the drug streptomycin from soil bacteria. It proved to be particularly effective against

A penicillin culture. *(Reproduced by permission of Custom Medical Stock Photo, Inc.)*

tuberculosis and was used in the treatment of many other bacterial infections. However, streptomycin caused harmful side effects, including hearing loss and vision problems that could lead to blindness.

The discovery of streptomycin led to the development of a new class of drugs called aminoglycosides (pronounced uh-MEE-noh-GLY-kuh-zides) that include neomycin (pronounced ne-oh-MY-sin), kanamycin (pronounced kan-uh-MY-sin), and gentamicin (pronounced jen-tuh-MY-sin). These antibiotics work against bacteria that are resistant to penicillin, but they tend to have many of the same side effects as streptomycin and are used only for a short time in cases of serious infection.

Following World War II (1939–45), drug companies in the United States conducted worldwide searches to find molds and soil bacteria that could be synthesized (made in a lab) into antibiotics. Aureomycin (pronounced aw-ree-oh-MY-sin), the first of the class of antibiotics known as tetracyclines (pronounced teh-truh-SY-kleenz), was discovered in 1945. Another group, the cephalosporins (pronounced seff-uh-low-SPOR-inz), came from a bacteria group living in a drainage pipe on the Italian coast. The antibiotics in this group have effects similar to those of penicillin. Erythromycin (pronounced uh-ree-throw-MY-sin), made from soil bacteria found in the Philippines, is used in patients allergic to penicillin as well as to fight penicillin-resistant bacteria. Bacitracin (pronounced bass-uh-TRAY-sin), an antibiotic made from bacteria, was developed in 1945 and is used as an ointment that is applied directly to the skin.

Resistance to antibiotics

Resistance of bacteria to the effects of antibiotics has become a major problem in the treatment of disease. Bacteria that are not killed or stopped by antibacterial drugs may change in form so that they resist attack against their cell walls—or even produce enzymes that kill the antibiotics. Prescribing antibiotic drugs when they are not needed, not taking the drugs as prescribed, and using the drugs for long periods of time all contribute to the development of resistant strains of bacteria. The use of antibiotics in animal feed to promote animal growth has also led to the development of hardier strains of antibiotic-resistant bacteria. Since the first use of antibiotics in the 1940s, most known bacterial diseases have built up a resistance to one or more antibiotics.

Measures to control the spread of antibiotic-resistant diseases include prescribing the drugs only when necessary, prescribing the correct antibiotic for the disease being treated, and making sure the patient understands the importance of taking *all* of the prescribed medication. Re-

search in newer types and combinations of drugs is ongoing, as is research in the development of vaccines to prevent bacterial infections.

Antibody and antigen

Antibodies, also called immunoglobulins, are proteins manufactured by the body that help fight against foreign substances called antigens. When an antigen enters the body, it stimulates the immune system to produce antibodies. (The immune system is the body's natural defense system.) The antibodies attach, or bind, themselves to the antigen and inactivate it.

Every healthy adult's body has small amounts of thousands of different antibodies. Each one is highly specialized to recognize just one kind of foreign substance. Antibody molecules are typically Y-shaped, with a binding site on each arm of the Y. The binding sites of each antibody, in turn, have a specific shape. Only antigens that match this shape will fit into them. The role of antibodies is to bind with antigens and inactivate them so that other bodily processes can take over, destroy, and remove the foreign substances from the body.

Antigens are any substance that stimulates the immune system to produce antibodies. Antigens can be bacteria, viruses, or fungi that cause infection and disease. They can also be substances, called allergens, that bring on an allergic reaction. Common allergens include dust, pollen, animal dander, bee stings, or certain foods. Blood transfusions containing antigens incompatible with those in the body's own blood will stimulate the production of antibodies, which can cause serious, potentially life-threatening reactions.

Classes of antibodies and their functions

There are five classes of antibodies, each having a different function. They are IgG, IgA, IgM, IgD, and IgE. Ig is the abbreviation for immunoglobulin, or antibody.

IgG antibodies are the most common and the most important. They circulate in the blood and other body fluids, defending against invading bacteria and viruses. The binding of IgG antibodies with bacterial or viral antigens activates other immune cells that engulf and destroy the antigens. The smallest of the antibodies, IgG moves easily across cell membranes. In humans, this mobility allows the IgG in a pregnant woman to

Words to Know

Allergen: A foreign substance that causes an allergic reaction in the body.

B cells: Cells produced in bone marrow that secrete antibodies.

Immune response: The production of antibodies in response to foreign substances in the body.

Immunity: The condition of being able to resist the effects of a particular disease.

Immunization: The process of making a person able to resist the effects of specific foreign antigens.

Inoculate: To introduce a foreign antigen into the body in order to stimulate the production of antibodies against it.

Monoclonal antibodies: Identical antibodies produced by cells cloned from a single cell.

Proteins: Large molecules that are essential to the structure and functioning of all living cells.

Vaccine: Preparation of a live weakened or killed microorganism of a particular disease administered to stimulate antibody production.

pass through the placenta to her fetus, providing a temporary defense to her unborn child.

IgA antibodies are present in tears, saliva, and mucus, as well as in secretions of the respiratory, reproductive, digestive, and urinary tracts. IgA functions to neutralize bacteria and viruses and prevent them from entering the body or reaching the internal organs.

IgM is present in the blood and is the largest of the antibodies, combining five Y-shaped units. It functions similarly to IgG in defending against antigens but cannot cross membranes because of its size. IgM is the main antibody produced in an initial attack by a specific bacterial or viral antigen, while IgG is usually produced in later infections caused by the same agent.

IgD is present in small amounts in the blood. This class of antibodies is found mostly on the surface of B cells—cells that produce and release antibodies. IgD assists B cells in recognizing specific antigens.

IgE antibodies are present in tiny amounts in serum (the watery part of body fluids) and are responsible for allergic reactions. IgE can bind to the surface of certain cells called mast cells, which contain strong chemicals, including histamine. (Histamines are substances released during an allergic reaction. They cause capillaries to dilate, muscles to contract, and gastric juices to be secreted.) When an allergen such as pollen binds with its specific IgE antibody, it stimulates the release of histamine from the mast cell. The irritating histamine causes the symptoms of an allergic reaction, such as runny nose, sneezing, and swollen tissues.

Tests that detect the presence of specific antibodies in the blood can be used to diagnose certain diseases. Antibodies are present whenever antigens provoke an immune reaction in the test serum.

The immune response

When a foreign substance enters the body for the first time, symptoms of disease may appear while the immune system is making antibodies to fight it. Subsequent attacks by the same antigen stimulate the immune memory to immediately produce large amounts of the antibody originally created. Because of this rapid response, there may be no symptoms of disease, and a person may not even be aware of exposure to the antigen. They have developed an immunity to it. This explains how people usually avoid getting certain diseases—such as chicken pox—more than once.

Immunization

Immunization is the process of making a person immune to a disease by inoculating them against it. Inoculation is the introduction of an antigen into the body—usually through an injection—to stimulate the production of antibodies.

The medical practice of immunization began at the end of the eighteenth century, when English physician Edward Jenner (1749–1823) successfully used extracts of body fluid from a dairymaid (a woman employed in a dairy) infected with cowpox (a mild disease) to inoculate a young boy against smallpox, a then-common and often fatal viral disease. Jenner called his method "vaccination," using the Latin words *vacca,* meaning "cow," and *vaccinia,* meaning "cowpox." Because the two diseases are caused by similar viruses that have the same antigens, antibodies that work against cowpox will also fight smallpox.

In 1885, a rabies vaccine developed by French scientist Louis Pasteur (1822–1895) from the spinal fluid of infected rabbits proved to be

Autoimmune Disease

Autoimmune diseases occur when the body's immune system loses the ability to recognize the difference between self and nonself. This results in the body producing antibodies, called autoantibodies, against its own tissues. Normally, antibodies are only produced against microorganisms that invade the body. The inability to make a distinction between self and nonself may lead to the destruction of body tissue and result in a number of chronic, debilitating diseases.

The cause of autoimmune reactions is not known. It is thought that infection by viruses and bacteria may trigger an autoimmune response. In addition, exposure to certain chemicals and ultraviolet light may alter proteins in the skin; the body may then become sensitive to these proteins and produce autoantibodies against them. Certain individuals seem to be genetically predisposed to have autoimmune responses. Some diseases that are associated with autoimmune responses are rheumatoid arthritis, lupus erythematosus, and pernicious anemia.

successful. Since that time, vaccines have been developed for many diseases, including diphtheria, polio, pertussis (whooping cough), measles, mumps, rubella (German measles), hepatitis, and influenza. Vaccines are made from either weakened live or killed microorganisms. When introduced into the body, they stimulate the production of antibodies, providing active immunity against bacterial and viral diseases.

Monoclonal antibodies

Monoclonal (*mono* means "one") antibodies are identical antibodies produced by clones (exact copies) of a single cell. The cell from which the clones are made is created by combining a B cell containing a specific antibody with a myeloma (a form of cancer) cell. The resulting hybrid produces the specific antibody of the parent B cell and divides indefinitely like the parent cancer cell. Clones of the hybrid cell produce virtually unlimited amounts of one type, or monoclonal, antibodies. Monoclonal antibodies are used in many medical diagnostic tests, such as pregnancy tests, and in the treatment of cancer and other diseases.

[*See also* **Allergy; Blood; Immune system; Rh factor; Transplant, surgical; Vaccine**]

Antiparticle

Antiparticles are subatomic particles that are the opposite of other subatomic particles in some way or another. In the case of the antielectron and the antiproton, this difference is a matter of charge. The electron is negatively charged, and the antielectron is positively charged; the proton is positively charged, and the antiproton is negatively charged. Since the neutron carries no electric charge, its antiparticle, the antineutron, is characterized has having a spin opposite to that of the neutron.

Dirac's hypothesis

The discovery of antiparticles is a rather remarkable scientific detective story. In the late 1920s, British physicist Paul Dirac (1902–1984) was working to improve the model of the atom then used by scientists. As he performed his mathematical calculations, he found that electrons should be expected in two energy states, one positive and one negative. However, the concept of negative energy was unknown to scientists at that time.

Dirac suggested that some electrons might carry a positive electrical charge, the opposite of that normally found in an electron. Scientists were skeptical about the idea. Electrons were well known, and the only form in which they had ever been observed was with a negative charge.

The dilemma was soon resolved, however. Only five years after Dirac proposed the concept of a positive electron, just such a particle was found by American physicist Carl Anderson (1905–1991). Anderson named the newly found particle a positron, for *posi*tive elec*tron.*

Other antiparticles and antimatter

Anderson's discovery raised an obvious question: If an antielectron exists, could there also be an antiproton, a proton with a negative charge? That question took much longer to answer than did Dirac's original problem. It was not until 1955 that Italian-American physicist Emilio Segrè (1905–1989) and American physicist Owen Chamberlain (1920–) produced antiprotons by colliding normal protons with each other inside a powerful cyclotron (atom-smashing machine).

If antielectrons and antiprotons exist, is it possible that antimatter also exists? Antimatter would consist of antiatoms made of antiprotons and antielectrons. The idea may seem bizarre because we have no experience with antimatter in our everyday lives. Scientists now believe that

antimatter is common in the universe, but we don't have any direct contact with it.

If antimatter does exist, locating it may be a problem. Scientists know that the collision of an antiparticle with its mirror image—an electron with a positron, for example—results in the annihilation of both, with the release of huge amounts of energy. Thus, any time matter comes into contact with antimatter, both are destroyed and converted into energy.

[*See also* **Subatomic particles**]

Antiseptics

Antisepsis (from the Greek, *anti,* meaning "against," and *sepsis,* meaning "decay") is the destruction or control of the growth of microorganisms on living tissue. Antiseptics are the substances that carry out antisepsis. They are applied externally to prevent bacterial growth, to treat skin infections, and to disinfect wounds.

Early uses of antiseptics

From the earliest times, physicians and healers were aware that certain substances appeared to stop infection and prevent spoilage. Egyptians used resins (natural organic substances), naphtha (flammable liquid hydrocarbon mixtures), and liquid pitch (tar) to decrease decay when preparing their dead for burial. The ancient Greeks and Romans recognized the antiseptic properties of wine, oil, and vinegar. Balsam was used in Europe from the Middle Ages (400–1450) times through the 1800s. Chloride of mercury was introduced as an antiseptic in 1766, and iodine became popular as an antiseptic treatment for wounds after its discovery in 1811.

Infection

None of these antiseptics could prevent the almost inevitable infection of wounds, particularly following surgery. Amputations, common in the 1800s, resulted in a high death rate due to infection. The introduction of anesthesia in 1846 added to the problem; it permitted longer and more complex operations, greatly increasing the likelihood of infection following surgery.

Another deadly form of infection was so-called childbed fever, a bacterial infection of the uterus that struck women who had just given birth. Epidemics of childbed fever raced through hospital maternity wards,

Words to Know

Antiseptic: A substance that prevents or stops the growth of microorganisms.

Carbolic acid: An acidic compound that, when diluted with water, is used as an antiseptic and disinfectant.

Childbed fever: A bacterial infection occurring in women following childbirth, causing fever and in some cases blood poisoning and possible death.

Infection: Invasion and multiplication of microorganisms in body tissues.

Sterilization: The process of making a substance free from microorganisms.

killing many new mothers. With no knowledge of the existence of bacteria, physicians had no concern for cleanliness. They wore street clothes or filthy operating gowns, used unclean instruments, and often failed to wash their hands properly before examining or operating on patients.

Advances in antisepsis

Some of the early advances in antisepsis came about because of attempts to understand and stop childbed fever. Toward the end of the eighteenth century, some doctors began to realize that lack of cleanliness might be related to the spread of infection. When doctors began washing their clothes and hands before examining patients, death rates from infection began to drop dramatically.

French chemist Louis Pasteur (1822–1895) helped to shed light on the source of infection by proving the existence of airborne microorganisms in the 1850s. English surgeon Joseph Lister (1827–1912) applied this new knowledge of bacteria to develop a successful system of antiseptic surgery. Concluding that microorganisms in the air caused the infection of wounds, Lister developed an antiseptic system using carbolic acid. Wounds and surrounding areas were sprayed with the acid to destroy infectious organisms. Multiple layers of dressing were then applied to wounds to protect them from new invasion by bacteria. Lister's method of antisepsis proved to be effective and was eventually adopted by physicians worldwide.

Improvements on Lister's techniques soon developed. The carbolic spray was abandoned in the 1880s in favor of cleanliness, sterilization, and topical antiseptics (antiseptics applied directly to a surface). A final obstacle to surgical antisepsis—germs on the human hands—was overcome by the introduction of rubber gloves. Today, sterile gloves are a requirement for surgical procedures.

Modern methods of preventing infection are very different from the techniques pioneered by Lister and others. Antibiotics, penicillin, and sulfa drugs fight infection inside the body, and aseptic (free from harmful microorganisms) methods such as sterilization prevent bacteria from existing in a given area. However, external antiseptics continue to be important.

Some commonly used antiseptics are hydrogen peroxide, alcohol, boric acid, iodine, formaldehyde, and hexachlorophene. Heat is also an extremely effective antiseptic and, at appropriate temperatures, can be used to disinfect many materials.

Aquaculture

Aquaculture refers to the breeding of fish and other aquatic animals for use as food. Aquaculture has long been practiced in China and other places in eastern Asia, where freshwater fish have been grown as food in managed ponds for thousands of years. Since the mid-twentieth century, however, the practice of aquaculture has spread around the world, with many new species of freshwater and marine animals being cultivated. By the late 1990s, aquaculture produced some 20 percent of the fish eaten by people around the world—over 20 million tons. The principle goal of aquaculture science is to develop systems by which fish can be grown and harvested at large rates, while not causing environmental damage in the process.

Fish farming

The oldest fish-farming systems were developed in Asia, and involved several species of freshwater fish. The first writings about the methods of fish farming date from about 2,500 years ago. The first species to be grown in aquaculture was probably the common carp, a fish native to China but now spread throughout the world.

Fish farming involves the management of all steps in the life cycle of the cultivated fish, from the production of eggs through the growth and eventual harvest of a high-quality, mature fish. Fish are most commonly

raised in artificial ponds or in cages or pens set into larger bodies of water, including the ocean. The fish are fed a nutritious diet—sometimes to excess so they may grow to their maximum size—and are administered medicines to maintain their health. Additionally, chemicals are frequently applied to their cages to prevent the fish from being eaten by predators. When the fish are mature, they are carefully harvested and processed.

In North America and Europe, the most commonly cultivated freshwater fish are species of trout, particularly brook trout and rainbow trout.

Fish farming. *(Reproduced by permission of JLM Visuals.)*

Other cultivated freshwater fish include channel catfish and the common carp. Saltwater or brackish (slightly salty) water species frequently cultivated include salmon and trout. Varieties of these are Atlantic salmon, Pacific salmon, and brown trout.

Invertebrate farming

Invertebrates are animals that lack a backbone or spinal column. The most common aquatic invertebrates cultivated around the world are species of oysters and mussels. In Asia, many species of oriental shrimps are bred, along with giant freshwater prawn. In Europe and North America, lobsters and various species of crayfishes are also cultivated.

Environmental impacts of aquaculture

Although aquaculture provides nutritious, high-quality foods for humans, it also severely harms the environment. When natural ecosystems (communities of plants and animals) such as tropical mangrove forests are turned into aquacultural systems, for instance, many native species in those ecosystems are displaced. Any remaining native species and the surrounding waters then face the threat of contamination from the drugs and toxic chemicals used in aquacultural management.

Arachnids

Arachnids (pronounced uh-RACK-nidz; class Arachnida) form the second-largest group of land arthropods (phylum Arthropoda) after the class Insecta. There are over 70,000 species of arachnids that include such familiar creatures as scorpions, spiders, harvestmen or daddy longlegs, and ticks and mites, as well as the less common whip scorpions, pseudoscorpions, and sun spiders. The marine horseshoe crabs and sea spiders are near relatives.

Physical characteristics

Arachnids have paired, jointed appendages (parts that are attached to the main body), a hardened exoskeleton (*exo* means "outer"), a segmented (divided into parts) body, and a well-developed head. Their body consists of two main parts: a fused head and thorax, and an abdomen. There are six pairs of appendages on the body: the first pair are clawlike fangs near the mouth used for grasping and cutting; the second pair serve

as general-purpose mouth parts that may be modified for special functions; and the last four pairs of appendages are the walking legs.

Most arachnids live on land and breathe by means of book lungs (so-called because their thin membranes are arranged like the pages of a book) or by tracheae (small tubes that distribute air from the outside throughout the body), or both. Most are flesh-eating predators. They feed by piercing the body of their prey and directly consuming its body fluids or by releasing digestive secretions that predigest the food before they eat it.

Scorpions

Scorpions have large, pincerlike second appendages and a segmented abdomen that is broad in front and narrows to become taillike, ending in a sharp pointed stinger. The stinger contains a pair of poison glands with openings at the tip. The venom is neurotoxic (poisonous to the nerves) but, except in a few species, is not potent enough to harm humans. Scorpions have book lungs for breathing. They engage in complex courtship behavior before mating, and newly hatched young are carried on the mother's back for one to two weeks. Scorpions are nocturnal (active at night) and feed mostly on insects. During the day they hide in crevices, under bark, or in other secluded places. They occur worldwide in tropical and subtropical regions.

Spiders

In spiders, the abdomen is separated from the joined head and thorax by a narrow waist. The large and powerful first appendages of some spiders contain poison glands at their base, while the tips serve as fangs that inject the poison into prey. The second appendages of spiders are long and leglike. In male spiders, these appendages each contain an organ used to transfer sperm to the female. Some species of spiders have only book lungs for breathing, while others have both book lungs and tracheae.

Spiders have organs called spinnerets at the tip of the abdomen that contain silk glands. The spinnerets draw secretions from the silk glands to produce fine threads of silk. These are used to build webs, ensnare prey, package sperm to be transferred to the female, and make egg sacs. Although all spiders produce silk, not all weave webs. Spiders have courtship patterns prior to mating that are quite varied.

Spiders are found worldwide and live in many different habitats—in burrows in the ground, in forests, in human habitations, and even under water. Spiders are predators, feeding mostly on insects. Despite their reputation as fearsome animals, they actually benefit humans by keeping

some insect populations under control. The bite of only about 30 species are dangerous, but rarely fatal, to humans.

Mites and ticks

Most mites and ticks are very small, mites being microscopic and ticks measuring only 0.2 to 1 inch (5 to 25 millimeters) in length. The oval body of these arachnids consists of the fused head and thorax and the abdomen. The first two pairs of appendages are small and are used for feeding. Adult ticks and mites have four pairs of walking legs, but the larvae have only three pairs. Breathing occurs through tracheal tubes.

The ticks are mostly bloodsucking parasites (organisms that feed on others) that attach themselves to the outer body of mammals, such as dogs, deer, and humans. In addition to injecting poison into the host while sucking blood, ticks can transmit other disease-causing organisms resulting in Rocky Mountain spotted fever, Lyme disease, relapsing fever, typhus, and Texas cattle fever. In order to lay eggs, a female tick must suck the host's blood until her body is filled; this feeding process is known as engorgement and requires attachment to the host for several days, after which the

A Cosmetid harvestman. *(Reproduced by permission of JLM Visuals.)*

engorged female may be three or more times her original size. The larval and nymphal stages likewise feed before they molt (shed their skin) and progress to the next stage of development. Ticks have specialized sense organs that enable them to locate a host more than 25 feet (about 7.5 meters) away.

Many mites are parasites of birds and mammals. They can be ectoparasites, feeding on the outer skin, or endoparasites, feeding on the underlying tissues. The ectoparasites live on the host's body surface, while the endoparasites dig tunnels under the host's skin in which they live and reproduce. While some parasitic mites transmit disease organisms, many cause diseases themselves. These include scabies and mange—contagious skin diseases characterized by inflammation, irritation, and intense itching.

Many more mites are free living, that is, not parasitic. Some, such as the chigger, are parasitic as larvae but free living in the nymph and adult stages. Free-living house dust mites cause allergies in many people. Others can cause the destruction of stored grain and other products.

Harvestmen (daddy longlegs)

Harvestmen, or daddy longlegs, look superficially like spiders but differ in many respects. They lack a waist separating the abdomen from the fused head and thorax, and their abdomen is segmented. They can ingest solid food as well as fluids. They do not produce silk and are nonpoisonous. Harvestmen feed on insects and contribute to insect control, although they are less important in this respect than spiders.

[*See also* **Arthropods**]

Archaeoastronomy

Archaeoastronomy is the study of the astronomy of ancient people. As a field it is relatively young, having formally begun only in the 1960s. Archaeoastronomers seek to know what celestial observations were made by an ancient society or culture. They then try to understand how those observations were made a part of the ancient society's religious customs, political life, and agricultural or hunting-gathering practices. For this reason, archaeoastronomy is often known as cultural astronomy.

Cosmology

Most ancient people developed a cosmology, or an understanding of the formation and structure of the universe and their place in it. Some

of these people thought the sky was inhabited by Sky People, gods, departed ancestors, or other forces. While ancient people worshiped these sky powers, they also believed the powers could be used to serve human goals. Thus a moon associated with important periods in the agricultural or hunting cycle would be honored to ensure better food supplies. A desire to have the sky powers serve the needs of humans may have motivated ancient societies to take up regular observations of the skies—in other words, astronomy.

Early observatories

Although any written records of ancient celestial observations have been lost to history, some of the physical signs of those activities remain. Among the most intriguing are the sites that, to a modern eye, could have been used as very early observatories.

Perhaps the most well known of these early sites is Stonehenge, which stands on Salisbury Plain in southern England. A group of massive standing stones, Stonehenge was built in three phases over a period of about 400 years, beginning around 1700 B.C. Most archaeologists believe the monument served as a ceremonial or religious structure. Some astronomers, however, believe Stonehenge could have been used to observe the winter solstice (the time when the rising of the Sun is farthest south) and the extreme rising and setting positions of the Moon.

While some ancient observing sites were simple, others were much more complex. Astronomical observations figured greatly in the culture of the Maya, native people of Central America and southern Mexico. Between 700 and 1263, the Maya built the elaborate city of Chichén Itzá on the northern Yucatan peninsula. The Caracol, a building probably designed as an observatory, and several other important ceremonial buildings at Chichén Itzá featured steeply ascending steps and ornately carved and painted relief sculptures. All were almost precisely aligned to face significant Sun and Venus positions in the sky.

Mayan life was dominated by the Sun and Venus, both of which the Maya connected to warfare. Venus, a fearful power, was also associated with sacrifice, fertility, rain, and maize (corn). Maya writings have been interpreted to indicate that raids were undertaken during important Venus positions, such as its first appearance as the morning star or the evening star. These raids have come to be called star war events. Ancient manuscripts also suggest the Maya had the ability to predict solar and lunar eclipses, accurate to within a day.

Archaeology

Archaeology is the scientific recovery and study of artifacts (objects made by humans) of past cultures. By examining artifacts and how and where they were found, archaeologists try to reconstruct the daily lives of the people of those cultures. Archaeological artifacts can include anything from ancient Greek pottery vessels found at the bottom of the sea to disposable plastic bottles found at modern dump sites. Thus, studies in archaeology can extend from the beginning of human prehistory to the most recent of modern times.

Disciplines

Since the mid-twentieth century, as new laboratory technologies have become available, the number of disciplines or fields of study that

Words to Know

Artifact: In archaeology, any human-made item that relates to the culture under study.

Classical archaeology: Archaeological research that deals with ancient history, ancient architecture, or any of the now-extinct civilizations, such as Greek, Egyptian, Roman, Aztec, or Mayan.

Historic archaeology: Archaeological studies focusing on the eras of recorded history.

Prehistoric archaeology: Archaeological studies focusing on eras before the appearance of written languages.

are linked to archaeology have expanded. However, the individual field archaeologist tends to focus his or her research on a specific culture or era in time.

Prehistoric archaeology. Prehistoric archaeologists seek to discover and write about the culture of ancient people who left behind no written history. Prehistory has no definite time period, having lasted for different times in different parts of the world. European prehistory ended with the appearance of primitive written languages around 2500 B.C. American prehistory, on the other hand, came to a close only 500 years ago when European explorers visited the New World and began keeping written reports of the people they had met.

Historic archaeology. Historic archaeologists seek a detailed understanding of cultures that have existed between the end of prehistory and the recent past. Their studies of a particular culture are much more complex. They are able to examine artifacts as well as review written documents pertaining to the time and place of that culture. A relatively new subdiscipline of historic archaeology is urban archaeology. It attempts to understand our current culture and cultural trends by examining material found at modern dump sites.

Classical archaeology. Classical archaeologists focus on the monumental art, architecture, and history of all ancient civilizations, including those of Greece, Egypt, and China. The roots of classical archaeology can be traced to the European fascination with Biblical studies and ancient

scholarship. The classical archaeologist is perhaps the most popular public stereotype. The Indiana Jones movie character, for example, is based on the fantastic exploits of a classical archaeologist.

Field methods

Before the twentieth century, most archaeology consisted of randomly collecting artifacts that could be found lying on the surface of sites or in caves. Because most early archaeological expeditions were financed

An archaeological excavation at Eldon Pueblo in Coconino National Forest in Arizona. *(Reproduced by permission of The Stock Market.)*

by private individuals and wealthy collectors, broken artifacts were often left behind. Only intact and highly crafted items were thought to have any value. Consequently, very little was learned about the cultures that made those artifacts.

Modern archaeologists are much more thorough in their research. They first survey or inspect the surface of an archaeological site to determine whether it might hold artifacts or other useful information about a culture. They then begin an organized excavation or digging operation to determine where the majority of artifacts are located at a site. Traditional tools used in excavation are picks, shovels, trowels, and hand-held shaker screens.

To place artifacts in time periods, archaeologists use a variety of dating techniques. A basic field technique is to observe the stratigraphy, or the arrangement or layers of rock and soil, while digging at a site. Soil and artifacts are deposited and layered one above the other like the layers of an onion. Artifacts found at deeper layers are much older than those found near the top. Beginning in the late 1940s, archaeologists began to use radiocarbon or C-14 dating, a highly accurate dating technique. A small sample of organic (living) material found at a site, such as wood or bone, is analyzed in a laboratory to determine the time period in which it existed.

These ruins at the Montezuma Castle National Monument in Arizona are remnants of a culture that flourished about A.D. 1200. *(Reproduced by permission of The Stock Market.)*

Current controversy

In the United States in the late twentieth century, controversy arose over the archaeological excavation of ancient Native American grave sites. For archaeologists, graves have provided a very important source of knowledge about past cultures. Although the people of prehistoric North American cultures left no written history, they buried their dead surrounded with material goods of their time.

Present-day Native Americans, however, believe ancestral graves should not be disturbed. If they are, then any remains and artifacts should be buried with ceremony. In response to Native American concerns, the U.S. government passed the Native American Grave Protection and Repatriation Act in 1990. This federal law penalizes anyone selling or trading illegally obtained Native American human remains and cultural items. It also requires all museums and universities that receive federal funding to repatriate or give back their Native American collections to tribes who claim cultural or religious ownership over those materials.

Archaeologists have countered that, in many cases, it is almost impossible to link ancient materials with modern Native American cultures. They also argue that museum materials are part of the heritage of the entire nation. Giving these materials back will prevent any further studies from being conducted in the future.

[*See also* **Dating techniques; Nautical archaeology**]

Arithmetic

Arithmetic is a branch of mathematics concerned with the addition, subtraction, multiplication, division, and extraction of roots of certain numbers known as real numbers. Real numbers are numbers with which you are familiar in everyday life: whole numbers, fractions, decimals, and roots, for example.

Early development of arithmetic

Arithmetic grew out of the need that people have for counting objects. For example, Stone Age men or women probably needed to count the number of children they had. Later, one person might want to know the number of oxen to be given away in exchange for a wife or husband. For many centuries, however, counting probably never went beyond the 10 stage, the number of fingers on which one could note the number of objects.

At some time, people began to realize that numbers could stand for something other than real objects. They understood that four oxen, four stones, four stars, and four baskets all had something in common, a "four-ness" that could be expressed by some symbol, such as 4. It appears that the ancient Sumerians of Mesopotamia (after 4000 B.C.) were the first to develop systematic ways of dealing with numbers in an abstract sense.

By far the most mathematically advanced of the ancient civilizations were the Egyptians, Babylonians, Indians, and Chinese. Each of these civilizations knew about and used whole numbers, fractions, and basic rules for dealing with such numbers. They used arithmetic to solve specific problems in areas such as trade and commerce, but they had not yet developed a theoretical system of arithmetic.

The establishment of such a theoretical arithmetic system occurred among the ancient Greeks in the third century B.C. The Greeks developed a set of theorems for dealing with numbers in the abstract sense, not just for the purpose of commerce.

Numbering system

The numbering system we use today is called the Hindu-Arabic system. It was developed by the Hindu civilization of India about 1,500 years ago and then brought to Europe by the Arabs in the Middle Ages (400–1450). During the seventeenth century, the Hindu-Arabic system completely replaced the Roman numeral system that had been in use earlier.

The Hindu-Arabic system is also called a decimal system because it is based on the number 10. The ten symbols used in the decimal system are 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. Other number systems are possible and, in fact, are also used today. Computers, for example, operate on a binary system that consists of only two numbers, 0 and 1. Our system of time uses the sexagesimal (pronounced sek-se-JES-em-el) system, consisting of the numbers 0 to 60.

A key feature of the decimal system is the concept of positional value. The value of a number depends not only on the specific digit (0, 1, 2, 3, 4, 5, 6, 7, 8, or 9) used, but also on the position of that digit in the number. For example, the number 532 is different from the number 325 or 253. The difference results from the fact that the 5, 3, and 2 appears in a different position in each case.

Another key feature of the decimal system is the digit zero (0). Ancient civilizations had no way of representing the concept of nothing. They apparently had little need to express the fact that they owned no

Words to Know

Associative law: An axiom that states that grouping numbers during addition or multiplication does not change the final result.

Axiom: A basic statement of fact that is stipulated as true without being subject to proof.

Closure property: An axiom that states that the result of the addition or multiplication of two real numbers is a real number.

Commutative law: An axiom of addition and multiplication that states that the order in which numbers are added or multiplied does not change the final result.

Hindu-Arabic number system: A positional number system that uses ten symbols to represent numbers and uses zero as a place holder. It is the number system that we use today.

Inverse operation: A mathematical operation that reverses the work of another operation; for example, subtraction is the inverse operation of addition.

oxen or had no children. Even the Roman numeral system has no way of representing the concept of zero (0). That concept is critical in the Hindu-Arabic number system, however, where 0 is treated in exactly the same way as any other number.

Axioms in arithmetic

The things that one does with numbers in arithmetic are said to be operations. The two basic operations in arithmetic are addition and multiplication, and the rules used to carry out these operations are referred to as the axioms of arithmetic. Axioms are statements that we accept as being true without asking that they be proved.

You may wonder why subtraction, division, raising a number of an exponent, and other mathematical operations are not listed as basic operations of arithmetic. The reason is that all of these operations can be considered as the extensions or inverse (backward operations) of addition or multiplication. For example, subtracting 3 from 9 is the same operation as adding the negative value of 3 (-3) to 9. In other words: $9 - 3$ is the

same as 9 + (−3). Similarly, division is the inverse operation of multiplication.

Three axioms control all addition operations. The first of these is called the commutative law and can be expressed by the equation a + b = b + a. In other words, it doesn't make any difference in which sequence numbers are added. The result will be the same. That concept is probably common sense to you. It doesn't make any difference whether you have $3 and earn $6 more ($3 + $6) or have $6 and earn $3 more ($6 + $3). In either case, you end up with $9.

The second axiom of arithmetic is the associative law, which can be expressed as a + (b + c) = (a + b) + c. In other words, if you have more than two items to be added, it doesn't make any difference how you group them for adding. A delivery person might collect $2 from a newspaper customer at one building and $5 and $7 from two customers in a second building; that is, $2 + ($5 + $7), or $14. Or that same delivery person might collect $2 and $5 from two customers in the first building and $7 from one customer in the second building, or ($2 + $5) + $7, or $14. In either case, the total collected is the same.

Finally, the closure axiom says that if you add any two real numbers, a + b, the result you get is also a real number.

Three multiplication axioms similar to the addition axioms also exist. The commutative law says that a × b = b × a. The associative law says that a × (b × c) = (a × b) × c. And the closure law says that a × b = a real number.

Other laws and axioms can be derived from the three basic laws of addition and multiplication. Those derivations are not essential to this discussion of arithmetic and will not be included here.

Kinds of numbers

The numbers used in arithmetic can be subdivided into various categories: whole numbers, integers, rational numbers, and irrational numbers. Whole numbers, also called natural numbers, include all of the positive integers plus zero. The numbers 3, 45, 189, and 498,992,353 are whole numbers. Integers are all whole positive and negative numbers. A list of integers would include 27, −14, 203, and −398,350.

Rational numbers are numbers that can be expressed as the ratio of two integers. Some examples include ½, ¾, 801/57, and 19/3,985. These numbers are also examples of fractions in which the first number (the number above the division sign) is the numerator, and the second number (the number below the division sign) is the denominator.

Finally, irrational numbers are numbers that cannot be expressed as the ratio of two integers. The ratio of the circumference of a circle (total length around) to its diameter is known by the name pi (π). The value of π can be calculated, but has no determinate (final) result. Depending on how long you calculate, the value of π can be expressed as 3.14 or 3.1416 or 3.14159265 or 3.141592653589793. The point is that no matter how long you look, you cannot find two integers that can be divided such that the answer will be the same as the value of π. Pi is, therefore, an irrational number.

The principles of mathematics provide the foundations for all other branches of mathematics. They also represent the most practical application of mathematics to everyday life. From determining the change received from a purchase to calculating the amount of sugar needed to make a batch of cookies, arithmetic skills are extremely important.

[*See also* **Algebra; Calculus; Function; Geometry; Trigonometry**]

Arthritis

Arthritis is a general term meaning an inflammation of a bone joint. More than 100 diseases have symptoms of bone joint inflammation or injury. This condition—the body's response to tissue damage—can cause pain, swelling, stiffness, and fatigue. Since the areas most commonly involved are the hands, arms, shoulders, hips, and legs, any action requiring movement of these parts becomes difficult. Arthritis is usually a chronic condition, meaning it persists throughout a person's life.

Osteoarthritis and rheumatoid arthritis are the two most common forms of the disease. Osteoarthritis occurs as a result of aging or injury. Rheumatoid arthritis is an autoimmune disease, meaning that the body produces antibodies (chemicals that fight against foreign substances in the body) that act against its own tissues.

Osteoarthritis

Osteoarthritis is the deterioration of the cartilage (connective tissue) covering the bones in the joints of the body. It is most often seen in people over the age of forty. Causes of osteoarthritis include wear and tear due to aging or overuse, injury, hereditary factors, and obesity. The wearing away of the cartilage results in the bones scraping against each other, causing the deep joint pain characteristic of this disease.

The joints most commonly affected by osteoarthritis are those of the knees, hips, and fingers. Other areas can be affected by injury or overuse. The condition can cause minor stiffness and pain, or it can result in severe disability. Treatment of osteoarthritis includes the use of anti-inflammatory drugs such as aspirin to reduce pain and swelling; supportive devices such as a brace, walker, or crutches; massage; moist heat; and rest.

Rheumatoid arthritis

Rheumatoid arthritis is one of the most crippling forms of arthritis. It is characterized by chronic inflammation of the lining of joints. It also affects the muscles, tendons, ligaments, and blood vessels surrounding these joints. Deformities can result from the deterioration of bone, muscle, and tissue, impairing function and affecting mobility. Rheumatoid arthritis can occur at any age but usually appears between the ages of thirty and sixty. Three times more women than men are stricken with this disease.

The cause of the chronic inflammation of rheumatoid arthritis is not known. It is suggested that a bacterial or viral infection may trigger an

A close-up of a hand deformed by rheumatoid arthritis; the knuckles are swollen and reddened and the fingers curve away from the thumb. *(Reproduced by permission of Photo Researchers, Inc.)*

Words to Know

Anti-inflammatory: A drug that reduces inflammation.

Autoimmune disease: A disease in which the body's defense system attacks its own tissues and organs.

Bone joint: A site in the body where two or more bones are connected.

Cartilage: The connective tissue that covers and protects the bones.

Immune response: The body's production of antibodies or some types of white blood cells in response to foreign substances.

autoimmune response in genetically predisposed people. People with rheumatoid arthritis produce antibodies that attack their own body tissues. This sets off an immune response that results in the body's release of chemicals that produce inflammation.

Treatment of rheumatoid arthritis includes aspirin therapy to reduce inflammation and relieve pain, application of heat to joints and muscles, rest, and physical therapy. In some cases, surgery may be required to reconstruct joints that are destroyed.

[*See also* **Antibody and Antigen**]

Arthropods

Arthropods are invertebrate (without a backbone) animals of the phylum Arthropoda that have a segmented body, jointed legs, and a tough outer covering or exoskeleton. They include insects, crustaceans (lobsters, crabs, shrimp, crayfish), millipedes, centipedes, horseshoe crabs, arachnids (spiders, ticks, and mites) and sea spiders. Together, arthropods comprise the largest and most varied group of invertebrates on Earth.

Characteristics

The bodies of arthropods are divided into different segments, each having a specialized role. The segments have numerous paired, jointed appendages (legs, antennae, claws, and external mouth parts) that serve

many varied functions. The exoskeleton acts as a protective covering to the underlying segmented body. It also provides an attachment for muscles and a barrier to water loss for animals living on land. It is made mostly of chitin (pronounced KIE-tuhn), a rigid, complex carbohydrate, and is usually covered by a hardened, waxy cuticle. The cuticle acts as a hinge between segments, allowing the body to bend and move to the right or left. Periodically, the rigid exoskeleton is shed in a process called molting. The temporarily soft animal then swells in size, and its new, larger exoskeleton hardens.

Arthropods are divided into chelicerates (pronounced kih-LIH-suh-ruhts), meaning "claw-horned ones," and mandibulates, meaning "jawed ones." The bodies of chelicerates are divided into two parts: a fused head and thorax, and an abdomen. They have no antennae, and most have four pairs of jointed legs. They are named for their first pair of appendages, which are modified as clawlike fangs used for feeding. The chelicerates include the arachnids, the marine horseshoe crabs, and the sea spiders.

The mandibulates have one or two pairs of appendages that function as antennae on their head, with the next pair modified as jaws for feeding. Included in this group are the crustaceans (crabs, lobsters, crayfish), the millipedes and centipedes, and the insects. The body of insects

A male black-winged damselfly. *(Reproduced by permission of Field Mark Publications.)*

is divided into three regions: a head, a thorax, and a clearly segmented abdomen. The thorax usually has three pairs of legs and two pairs of wings attached to it. Centipedes and millipedes have a head and a narrow, segmented trunk, the former having one pair of legs per segment and the latter having two. Crustaceans have many different body shapes. In most, the head and thorax are fused and separate from the abdomen. Their segmented bodies are often hidden by their hard outer shell.

Arthropods usually have more than one pair of eyes, which may include both simple and compound pairs. (A compound eye is made up of many separate units for receiving light, each with its own lens.) Breathing in land-arthropods is usually accomplished through air tubes called tracheae. Oxygen enters the air tubes from the outside through small openings in the body and is distributed to all the tissues. Arachnids, such as spiders, also breathe through book lungs, thin flaps of tissue arranged like the pages of a book. Arthropods that live in water generally breathe through gills.

Life cycle

Arthropods begin as eggs and can follow several different life cycles, depending on the group. Some insects hatch as miniature adults, while others hatch as nymphs and develop by stages into adults. Still others hatch as larvae and enter a resting stage as pupae, during which they may be enclosed in a cocoon and go through internal changes before emerging as adults. During their various developmental stages, known as metamorphosis, arthropods may shed their outer covering several times (molt).

Ecological importance

Arthropods are of ecological importance because of their sheer numbers and extreme diversity. More than 874,000 living species of arthropods have been identified, making up more than 80 percent of all named species of animals. However, it is estimated that many more thousands of arthropods exist that have not yet been named. Most of these unnamed species are small beetles and other insects, and most of these occur in old-growth tropical rain forests—areas that have not yet been well explored.

Arthropods occupy an enormous variety of Earth's habitats. Most species of crustaceans live in water (that is, are aquatic), although a few such as wood lice and land crabs occur in moist habitats on land. The spiders, mites, scorpions, and other arachnids are almost entirely land animals, as are the extremely diverse insects.

Arthropods are both harmful and helpful to humans. A few species are transmitters of bacteria or viruses that cause diseases such as malaria, yellow fever, encephalitis, and Lyme disease. Scorpions, some spiders, and bees and wasps have poison glands and can hurt or even (though rarely) kill people by injecting poison through stingers. Some arthropods are a nutritious source of food in many parts of the world, and insects play an important role in pollination (a process necessary for production in many plants).

[*See also* **Arachnids; Crustaceans; Insects**]

Artificial fibers

An artificial fiber is a threadlike material invented by human researchers. Such fibers do not exist naturally. Some examples of artificial fibers include nylon, rayon, Dacron™, and Orlon™. These terms illustrate that some names of artificial fibers are, or have become, common chemical names (nylon and rayon), while others (Dacron™ and Orlon™) are proprietary names. Proprietary names are names that are owned by some company and are properly written to indicate that the name is a registered trademark (™).

Most artificial fibers are polymers. A polymer is a chemical substance that is produced when one or two small molecules are reacted with each other over and over again. The beginning molecule used in making a polymer is called a monomer. When two different monomers are used, the product that results is called a copolymer.

An example of a copolymer is nylon, first invented by American chemist Wallace Carothers (1896–1937) in 1928. The two monomers of which nylon is made are complicated substances called adipic acid and hexamethylenediamine. For simplicity, call the first monomer A and the second monomer B. A molecule of nylon, then, has a structure something like this:

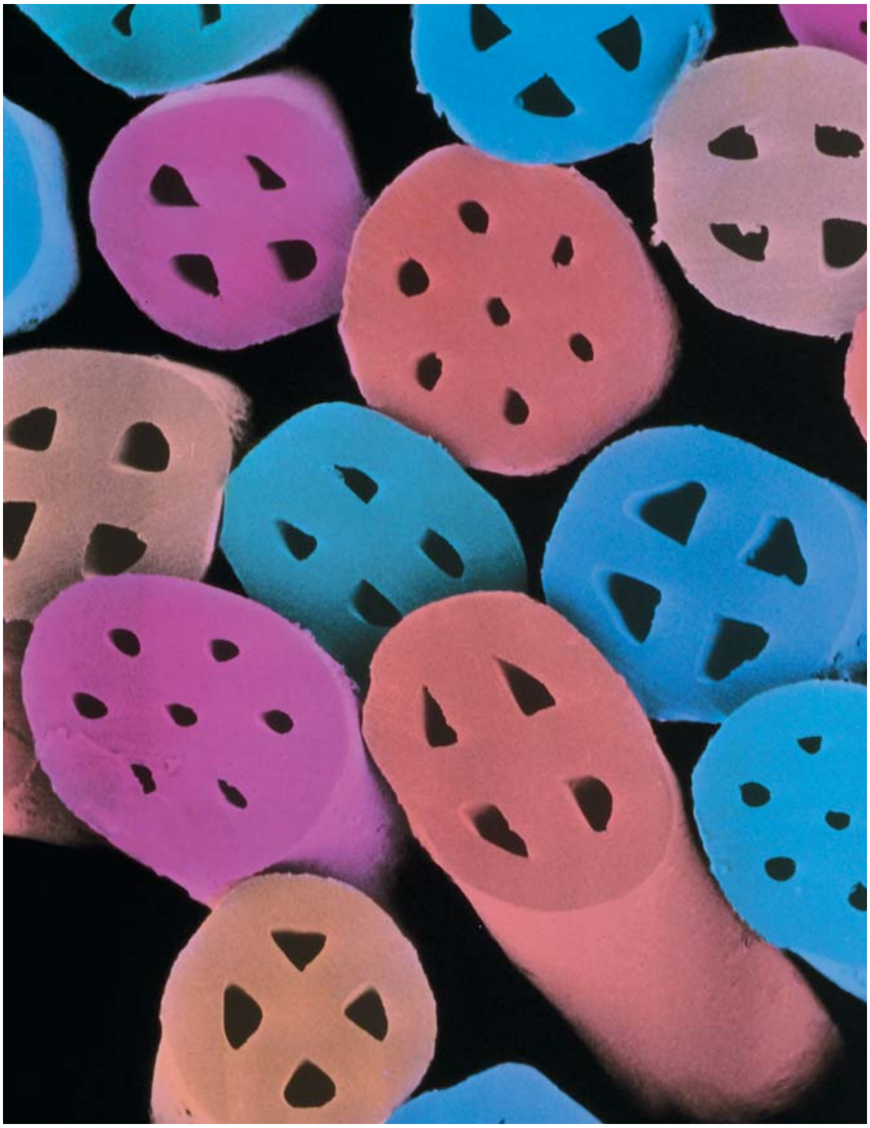
-A-B-A-B-A-B-A-B-A-B-A-B-

The dashes at the beginning and end of the molecule indicate that the -A-B- sequences goes on and on until it contains hundreds or thousands of monomer units.

The usual process by which artificial fibers are produced is called spinning. When a polymer is first produced, it is generally a thick, vis-

cous (sticky) liquid. That liquid is forced through a disk containing fine holes known as a spinneret. The spinneret may be suspended in the air or it may be submerged under water. As the polymeric liquid passes through the spinneret holes, it become solid, forming long, thin threads.

The properties of an artificial fiber can be changed in a number of ways, including the way in which the polymer is first produced, additives that may be attached to the polymer, and the way the polymer is processed through the spinneret.



A scanning electron micrograph of fibers of a dacron polyester material used in sleeping bags. The core of each fiber has up to seven air cavities that increase its insulating ability. *(Reproduced by permission of Photo Researchers, Inc.)*

Other synthetic fibers

Artificial fibers can be made by processes other than polymerization. Glass fibers, for example, can be produced by melting certain kinds of glass and then forcing the melted material through a spinneret to form long, thin threads. Many of these artificial fibers not made from polymers are the result of recent chemical research and show exciting promise for new applications in industry.

[*See also* **Polymer**]

Artificial intelligence

Artificial intelligence (AI) is a subfield of computer science that focuses on creating computer software that imitates human learning and reasoning. Computers can out-perform people when it comes to storing information, solving numerical problems, and doing repetitive tasks. Computer programmers originally designed software that accomplished these tasks by completing algorithms, or clearly defined sets of instructions. In contrast, programmers design AI software to give the computer only the problem, not the steps necessary to solve it.

Overview of artificial intelligence

All AI programs are built on two foundations: a knowledge base and an inferencing capability (inferencing means to draw a conclusion based on facts and prior knowledge). A knowledge base is made up of many different pieces of information: facts, concepts, theories, procedures, and relationships. Where conventional computer software must follow a strictly logical series of steps to reach a conclusion (algorithm), AI software uses the techniques of search and pattern matching. The computer is given some initial information and then searches the knowledge base for specific conditions or patterns that fit the problem to be solved. This special ability of AI programs—to reach a solution based on facts rather than on a preset series of steps—is what most closely resembles the thinking function of the human brain. In addition to problem solving, AI has many applications, including expert systems, natural language processing, and robotics.

Expert systems. The expert system is an AI program that contains the essential knowledge of a particular specialty or field, such as medicine, law, or finance. A simple database containing information on a par-

Words to Know

Algorithm: Clearly defined set of instructions for solving a problem in a fixed number of steps.

Expert system: AI program that contains the essential knowledge of a particular specialty or field such as medicine or law.

Natural language: Language first learned as a child; native tongue.

Robotics: Study of robots, machines that can be programmed to perform manual duties.

Software: Set of programs or instructions controlling a computer's functions.

ticular subject can only give the user independent facts about the subject. An expert system, on the other hand, uses reasoning to draw conclusions from stored information. Expert systems are intended to act as intelligent assistants to human experts.

Natural language processing. Most conventional computer languages consist of a combination of symbols, numbers, and some words. These complex languages may take several years for a computer user to master. Computers programmed to respond to our natural language—our everyday speech—are easier and more effective to use. In its simplest form, a natural language processing program works like this: a computer user types a sentence, phrase, or words on the keyboard. After searching its knowledge base for references to every word, the program then responds appropriately.

An example of a computer with a natural language processor is the computerized card catalog available in many public libraries. If you want a list of books on a specific topic or subject, you type in the appropriate phrase. You are asking the computer—in English—to tell you what is available on the topic. The computer usually responds in a very short time—in English—with a list of books along with call numbers so you can find what you need.

Robotics. Robotics is the study of robots, which are machines that can be programmed to perform manual duties. Most robots in use today

Algorithms

An algorithm is a set of instructions that indicate a method for accomplishing a task in mathematics or some other field. People use algorithms every day, usually without even thinking about it. When you multiply two numbers with a hand calculator, for example, the first step is to enter one number on the keyboard. The next step is to press the multiplication sign (×) on the keyboard. Then you enter the second number on the keyboard. Finally you press the equals sign (=) to obtain the answer. This series of four steps constitutes an algorithm for multiplying two numbers. Many algorithms are much more complicated than this one. They may involve dozens or even hundreds of steps.

perform various repetitive tasks in an industrial setting. These robots typically are used in factory assembly lines or in hazardous waste facilities to handle substances far too dangerous for humans to handle safely.

Research is being conducted in the field of intelligent robots—those that can understand their environment and respond to any changes. AI programs allow a robot to gather information about its surroundings by using a contact sensor to physically touch an object, a camera to record visual observations, or an environmental sensor to note changes in temperature or radiation (energy in the form of waves or particles).

Intelligent machines?

The question of whether computers can really think is still being debated. Some machines seem to mirror human intelligence, like I.B.M.'s chess-playing computer, Deep Blue, or the robotic artist named Aaron that produces paintings that could easily pass for human work. But most researchers in the field of artificial intelligence admit that at the beginning of the twenty-first century, machines do not have the subtlety, depth, richness, and range of human intelligence. Even with the most sophisticated software, a computer can only use the information it is given in the way it is told to use it. The real question is how this technology can best serve the interests of people.

[*See also* **Automation; Computer, analog; Computer, digital; Computer software; Cybernetics; Robotics**]

Asbestos

Asbestos is the general name for a wide variety of silicate minerals, primarily silicates of calcium, magnesium, and iron. Silicates are commonly occurring minerals that all contain a characteristic combination of silicon and oxygen similar to that found in silicon dioxide (sand). The two most common families of asbestos minerals are called the amphiboles and serpentines. Most people know of asbestos today because of health problems attributed to it. Prolonged exposure results in a pneumonia-like condition known as asbestosis, which is often fatal.

More than a dozen minerals are classified under the general name of asbestos. These minerals differ from each other in many ways, but all have one important property in common: their fibrous character. The most common form of asbestos, chrysotile, consists of long, hollow, cylindrical fibers that are about 25 nanometers in diameter. (A nanometer is one-billionth of a meter.)

All asbestos fibers are more or less rigid and more or less noncombustible. Their resistance to burning is, in fact, responsible for their name. The Greek word *asbeston* means "noncombustible."

History

Because of its unusual properties, asbestos has an interesting history. The ancient Romans were said to have woven asbestos wicks for the lamps used by the vestal virgins. (The vestal virgins were women who watched over the temple to the goddess Vesta.) And a story is also told about the Frankish king and emperor of the West named Charlemagne (742–814), who sought to impress barbarian visitors by throwing a tablecloth woven of asbestos into a fire.

One of the first complete scientific descriptions of asbestos was provided by J. P. Tournefort in the early 1700s. He explained that the substance "softens in Oil and thereby acquires suppleness enough to be spun into Threads; it makes Purses and Handkerchiefs, which not only resist the Fire, but are whiten'd and cleansed by it." Travelers to North America in the 1750s also told of widespread use of asbestos among both colonists and Native Americans.

Obtaining asbestos

The largest supplier of asbestos minerals has traditionally been Russia (or the former Soviet Union), which accounted for about half of all

the asbestos mined in the world. The second largest source has been Canada (about 30 percent of the world's output), followed by the European nations, Zimbabwe, China, South Africa, and the United States.

Asbestos occurs either in seams that run at or just beneath Earth's surface or in veins that may go as deep as 300 meters. One method of quarrying the seams is known as block caving. In this process, trenches are dug underneath an asbestos seam and the whole section is then allowed to fall and break apart. In another technique, open seams of the mineral are plowed up and allowed to dry in air.

Underground veins are mined in much the same way as coal. The distinctive fibrous character of asbestos makes it relatively easy to separate from other rocky material with which it is found.

Processing

After asbestos is removed from Earth, it is processed in order to divide it into groups according to fiber length. Longer fibers are separated out for weaving into a clothlike material. Shorter fibers, known as shingles, are combined with each other and often with other materials to make some type of composite (mixed) product. Perhaps the best known of these composites is asbestos cement, invented in the late 1800s. Asbestos ce-

Sample of serpentine asbestos. Its long, cylindrical fibers are visible. *(Reproduced by permission of JLM Visuals.)*

Words to Know

Asbestos cement: A composite material made by mixing together cement and asbestos.

Asbestosis: A disorder that affects the respiratory tract as a result of inhaling asbestos fibers, leading eventually to a variety of serious and generally fatal respiratory illnesses.

Fabricate: To shape a material into a form that has some commercial value, as in shaping asbestos fibers into a flat or corrugated board.

Fiber: A long, threadlike material, often used in the manufacture of cloth.

Quarrying: A method by which some commercially valuable substance is extracted, usually from Earth's surface.

Shingles: A name given to shorter fibers of asbestos.

ment contains about 12.5 percent asbestos and the remainder, portland cement, which is used for a variety of construction purposes.

Uses

Most asbestos cement is fabricated (processed) into corrugated (wavy) or flat sheets to be used as a building material in industrial and agricultural structures. The cement can be altered by adding various materials to improve its thermal (heat), acoustical (sound), and other properties. Some asbestos cement is also used in the manufacture of heating ducts and piping.

Long-fiber asbestos is more commonly used in the production of fabrics. It can be woven alone or with other fibers (such as glass fibers) to make protective clothing for fire fighters, brake and clutch linings, electrical insulation, moldings for automobile components, and linings for chemical containers.

Health considerations

During the first half of the twentieth century, asbestos cement was widely used for construction. In many respects, it was the ideal building

material: strong, fireproof, and a good insulator. Untold numbers of homes, schools, office buildings, naval ships, and other structures were built with linings of asbestos.

After World War II (1939–45), scientists discovered that asbestos fibers can cause a variety of respiratory disorders in humans, such as lung cancer and asbestosis, a pneumonia-like condition. Discovering the relationship between asbestos and these conditions took a long time; the disorders commonly do not appear until 20 years or more after a person is exposed to asbestos.

Individuals most at risk for asbestos-related problems are those continually exposed to the mineral fibers. This includes those who work in asbestos mining and processing as well as those who use the product in some other manufacturing line, as in the production of brake linings. Over the past two decades, massive efforts have been made to remove asbestos-based materials from buildings where they are especially likely to pose health risks, as in school buildings and public auditoriums. Recent critics of asbestos removal maintain that—if not done properly—the removal process actually intensifies the problem by spreading more asbestos fibers into the air.

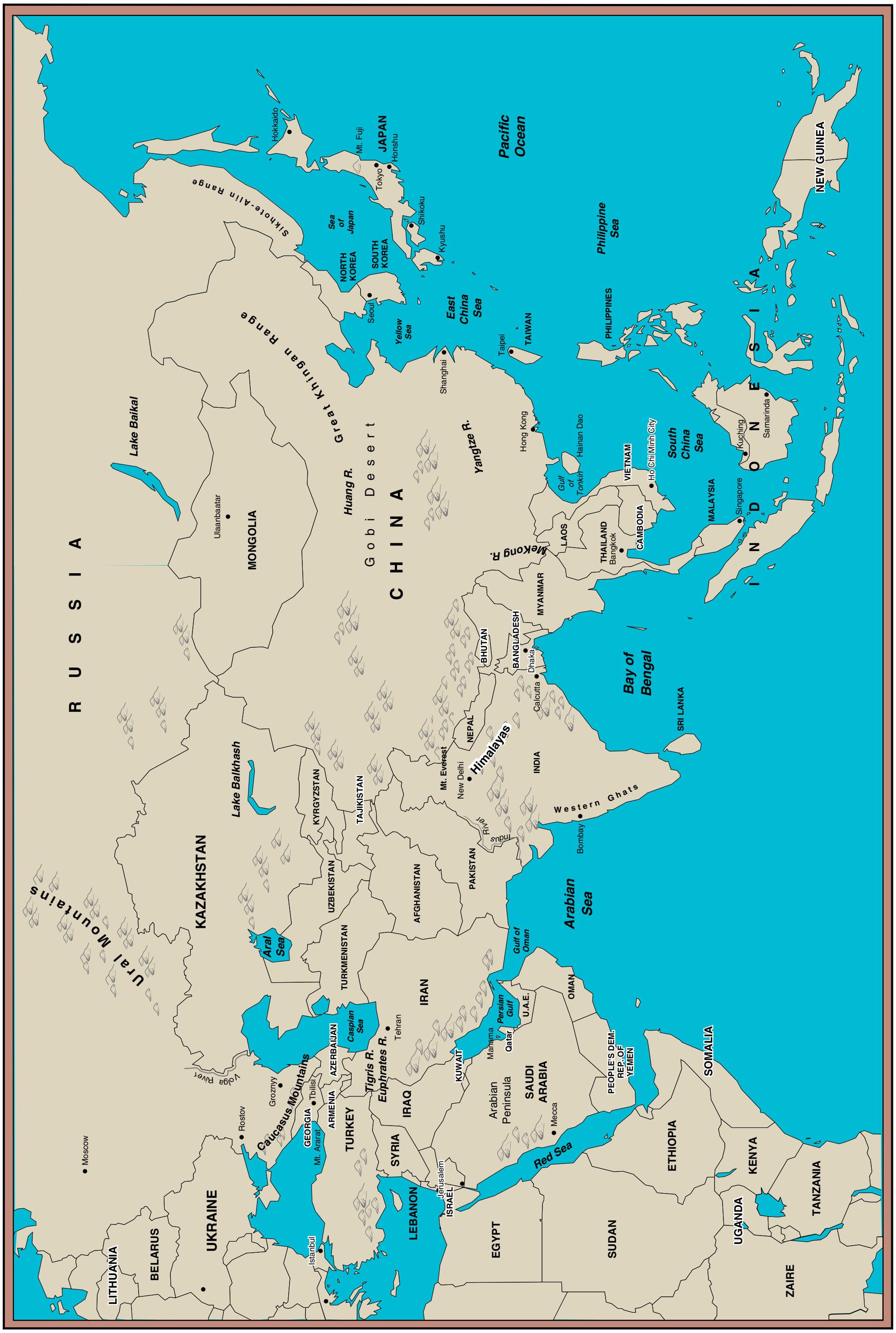
[*See also* **Respiratory system**]

Asia

Asia is the world's largest continent, encompassing an area of 17,139,000 square miles (44,390,000 square kilometers), almost 30 percent of the world's land area. Because Asia covers such an enormous area and contains so many countries and islands, its exact borders remain unclear. In the broadest sense, it includes central and eastern Russia, the countries of the Arabian Peninsula, the far eastern countries, the Indian subcontinent, and numerous island chains. It is convenient to divide this huge area into five regions: the Middle East, South Asia, Central Asia, the Far East, and Southeast Asia.

The Himalayan mountains, which are the highest and youngest mountain range in the world, stretch across the Asian continent from Afghanistan to Burma. Mount Everest, the highest of the Himalayan peaks, reaches an altitude of 29,028 feet (8,848 meters). There are many famous deserts in Asia, including the Gobi, the Thar, and Rub'al-Khali ("empty quarter"). The continent contains some of the world's largest lakes and longest-running rivers. It also features a wide range of climatic

Opposite page: Asia. *(Reproduced by permission of The Gale Group.)*


RUSSIA
Moscow
LITHUANIA
BELARUS
UKRAINE
Rostov
Volga River
Ural Mountains
KAZAKHSTAN
Lake Balkhash
Aral Sea
UZBEKISTAN
TURKMENISTAN
KYRGYZSTAN
TAJIKISTAN
AFGHANISTAN
PAKISTAN
Indus River
Grozny
Caucasus Mountains
GEORGIA
Tbilisi
ARMENIA
Mt. Ararat
AZERBAIJAN
Caspian Sea
TURKEY
Istanbul
SYRIA
LEBANON
ISRAEL
Jerusalem
IRAQ
Tigris R.
Euphrates R.
IRAN
Tehran
KUWAIT
Manama
Qatar
Persian Gulf
U.A.E.
Gulf of Oman
OMAN
SAUDI ARABIA
Arabian Peninsula
Mecca
Red Sea
PEOPLE'S DEM. REP. OF YEMEN
EGYPT
SUDAN
ETHIOPIA
SOMALIA
KENYA
UGANDA
TANZANIA
ZAIRE
Arabian Sea
Bombay
Western Ghats
INDIA
New Delhi
Mt. Everest
Himalayas
NEPAL
BHUTAN
BANGLADESH
Dhaka
Calcutta
Bay of Bengal
SRI LANKA
MYANMAR
Mekong R.
LAOS
THAILAND
Bangkok
CAMBODIA
VIETNAM
Ho Chi Minh City
MALAYSIA
Singapore
Kuching
Samarinda
South China Sea
Gulf of Tonkin
Hainan Dao
Hong Kong
CHINA
Gobi Desert
Huang R.
Yangtze R.
Shanghai
MONGOLIA
Ulaanbaatar
Lake Baikal
Great Khingan Range
Sikhote-Alin Range
NORTH KOREA
SOUTH KOREA
Seoul
Yellow Sea
East China Sea
TAIWAN
Taipei
PHILIPPINES
Sea of Japan
JAPAN
Hokkaido
Honshu
Tokyo
Mt. Fuji
Shikoku
Kyushu
Pacific Ocean
Philippine Sea
INDONESIA
NEW GUINEA

Words to Know

Coniferous: Refers to trees, such as pines and firs, that bear cones and have needle-like leaves that are not shed all at once.

Deciduous: Refers to trees, such as oaks and maples, that shed all their leaves at the end of the growing season.

Delta: Triangular-shaped area where a river flows into an ocean or lake, depositing sand, mud, and other sediment it has carried along its flow.

Plateau: An elevated area which is flat on top; also called tableland.

Seismic: Related to earthquakes.

Steppe: Wide expanses of relatively level plains, found in cool climates.

zones, from the tropical jungles of the south to the arctic wastelands of the north.

The Middle East

The Middle East region contains the countries of Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, and Yemen. Most of these countries lie on the Arabian Peninsula, an area that stretches from Turkey in the northwest to Yemen in the south. The peninsula is bordered on the east by the Persian Gulf and on the west by the Red Sea. In general, precipitation is low and the climate is extremely dry. Much of the area is still a desert wilderness. Vegetation is mostly desert scrub. One area that is well-watered and fertile is the historic Fertile Crescent, which includes parts of Iraq, Israel, Jordan, Lebanon, and Syria. The fertile river plains and valleys of this area are watered by the Euphrates and Tigris Rivers.

The Dead Sea, located in Israel, is the lowest point on Earth's landmasses, lying 1,290 feet (393 meters) below sea level. It takes its name from the fact that it is one of the saltiest bodies of water in the world and, therefore, supports no aquatic life. It yields large amounts of potassium chloride, magnesium bromide, and many other mineral salts. Lake Tuz, in Turkey, also has a high level of salinity and is used as a source of salt.

Large oil reserves are found in most Middle Eastern countries, especially Saudi Arabia. The world's largest oil field is in southern Saudi

Arabia in the Rub'al-Khali Desert. This virtually uninhabited desert covers an area of about 250,000 square miles (647,500 square kilometers). It features sand dunes that rise to over 66 feet (200 meters).

Steep mountain ranges divide up both Lebanon and Turkey. The ranges in Lebanon have been carved by erosion into intricate clefts and valleys, lending the landscape an unusual rugged beauty. Turkey's highest peak, Mount Ararat (legendary resting place of Noah's ark), reaches 16,945 feet (5,165 meters). Turkey is also a country of seismic activity, and earthquakes are frequent.

South Asia

The South Asia region contains the countries of Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka. Great mountain barriers isolate this region from the rest of Asia. South Asia can be further divided into three subregions: the Himalayan Mountains, the Ganges Plain, and the Indian peninsula.

The Himalayas stretch about 1,500 miles (2,410 kilometers) across Asia, from Pakistan through India, Nepal, Tibet, and Bhutan. They range from 150 to 210 miles (250 to 350 kilometers) wide. The Himalayas are the highest mountains in the world, and are still being pushed upwards at a rate of about 2.5 inches (6.3 centimeters) a year. This great mountain range originated about 25 to 70 million years ago when the Indian subcontinent collided with Asia, forcing Earth's crust to fold. The Himalayas are the youngest mountains in the world, which accounts in part for their great height. Some 30 peaks in the Himalayas rise to more than 25,000 feet (7,620 meters), including Mount Everest between Nepal and Tibet. Not surprisingly, many of the mountains in this range are covered with glaciers.

South of the Himalayan mountains, lying in northern India, is the Ganges Plain, which holds the Ganges and Brahmaputra Rivers. The plain is one of the most well-watered and fertile regions of Asia, fed by many tributaries and by the snow and ice from nearby mountains. Because the majority of the plain is flat and close to sea level, however, it is plagued by frequent flooding.

South of the plain is the Indian peninsula, a region of low plateaus and river valleys. It is bounded on the west by the Ghat mountain range and on the north by the Thar Desert, a desolate region about 500 miles (800 kilometers) long and 250 miles (400 kilometers) wide. In its southern extent, the Thar borders on salt marshes and the great lava expanse called the Deccan plateau.

Central Asia

Central Asia includes the countries of Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Mongolia, Russia (central and eastern areas), Tajikistan, Turkmenistan, and Uzbekistan. Many of the areas in this region are cold and inhospitable. Plateaus, desert and forest steppes (wide expanses of relatively level plains), and irrigated farmland mark a majority of the areas in this region. Mountains rise mainly along the east coast of Russia.

Temperatures are often extreme in this region. In Mongolia, temperatures fluctuate wildly, from −40 to 104°F (−40 to 40°C). The top one-third of Russian Siberia lies within the Arctic Circle. The climate is very harsh. Temperatures fall as low as −94°F (−70°C), and there are only 100 days a year when it climbs above 50°F (10°C).

Lake Baikal, in southern Siberia, is the largest freshwater lake in both Asia and Europe. It covers an area of 12,160 square miles (31,494 square kilometers). The world's deepest lake, it has a maximum depth of 5,714 feet (1,742 meters). Baikal is rich in aquatic life. It is the only habitat of 600 kinds of plants and 1,200 kinds of animals, making it home to two-thirds of the freshwater species on Earth.

Terraced farms along Jomosom Trail in the Himalayas in Nepal. *(Reproduced by permission of Susan D. Rock.)*

The Far East

The Far East region contains the countries of China, Japan, North Korea, South Korea, and Taiwan. Most of these countries are rugged and mountainous. Many forested areas exist in the region, though, since rainfall is more plentiful than in the Middle East.

Volcanic activity and the movement of Earth's crust formed many island chains in this region. Japan is a country of frequent earthquakes and intense volcanic activity, with more than 60 active volcanoes. Over 70 percent of its terrain is mountainous. The highest mountain peak is an extinct volcano called Mount Fuji, which reaches an altitude of 12,388 feet (3,776 meters).

The Korean peninsula, on which North and South Korea lie, is also very mountainous. Lowlands and plains compose only about 20 to 30 percent of the peninsula's land area. Mount Paektu, an extinct volcano with a lake in its crater, is the highest point on the peninsula at 9,003 feet (2,744 meters).

In contrast, China contains many regions of fertile land and temperate climate. In northern China, most of the land is made up of fertile plains. Running through this area is the Yellow River (Huang He), which has been called China's Sorrow because of its great flooding. Central China also contains many rivers, including the great Yangtze. Several freshwater lakes are spread across this area. The largest of these, and the largest in China, is called the Poyang. The climate in southern China is tropical and the land is very fertile. The Pearl River delta, which lies in this region, has some of the richest agricultural land in China.

In western China, fertile lands give way to cold and arid regions of mountains and highlands. The Gobi Desert, the fifth largest desert in the world, is located in northwestern China. The Gobi, which means "waterless place," encompasses an area of 500,000 square miles (1,295,000 square kilometers) and averages two to four inches of rainfall a year.

Southeast Asia

Southeast Asia includes the countries of Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. The region is quite tropical and tends to be very humid and rainy. Mountainous areas are extremely rugged. Both mountains and highlands throughout the region are covered by jungles and forests, including tropical rain forests, deciduous forests, and coniferous forests. Because these remote areas are often inaccessible to humans, they have become home for many unusual animal and plant species.

Great rivers often drain the mountainous areas in the region, flowing into plains. In Thailand, the Chao Phraya River flows through a central lowland plain, making the surrounding land rich and fertile. The Mekong River, which begins in the highlands of Tibet, flows through Laos along most of its western boundary with Thailand before entering Cambodia. In the center of Cambodia is the Tonle Sap (Great Lake), and many of the rivers that water Cambodia flow into this lake. During the winter, when the Mekong River floods, it forces the flow back from the Tonle Sap into its tributaries, flooding the surrounding area with rich silt. The Mekong finally reaches the South China Sea in south Vietnam where it forms a wide delta. Extremely fertile, this delta is one of the greatest rice-growing areas in Asia.

The island chains of Malaysia, Indonesia, and the Philippines are extremely fertile and have large regions of tropical rain forests containing an enormous variety of native wildlife. Indonesia and the Philippines are also sites of much volcanic activity. Indonesia has an estimated 100 active volcanoes.

Asteroid

Asteroids are relatively small, rocky chunks of matter that shine like small stars, but orbit the Sun like planets. Most asteroids, or minor planets as they are sometimes called, are made of carbon-rich rock, while others (those farthest from the Sun) contain iron, nickel, and a few other elements. One asteroid, Pholus, is coated with a red material that may be organic compounds similar to those that form living material.

Asteroids vary in size from 580 miles (940 kilometers) in diameter (Ceres, the first asteroid discovered) to 33 feet (10 meters) in diameter. Most are so small their size cannot be measured directly. They are generally irregular in shape and vary in brightness as they rotate.

Scientists once thought asteroids were remnants of exploded planets. This theory was soon discarded, however, because asteroids are so small. All the known asteroids combined would form an object much smaller than Earth's moon. Scientists now believe that asteroids are planetesimals—ancient chunks of matter left over from the formation of the solar system that never came together to form a planet, perhaps because of the strong gravitational influence of Jupiter. Asteroid-like objects were among the first structures to form in our solar system some 4.6 billion years ago. For this reason, asteroids can provide valuable information about the beginnings of our solar system.

Words to Know

Apollo objects: Group of asteroids that crosses Earth's orbit.

Bode's Law: Simple yet flawed mathematical formula establishing the distances of planets from the Sun.

Kirkwood gaps: Areas separating distinct asteroid belts that lie between the orbits of Mars and Jupiter.

Planetesimals: Ancient chunks of matter that are leftover "building blocks" from the formation of the solar system.

The discovery of asteroids

For years, astronomers theorized about a hidden planet between Mars and Jupiter. In 1766, German astronomer Johann Titius devised a formula for calculating distances between planets. The formula predicted the existence of a planet between Mars and Jupiter. (Although Titius devised the formula, it did not receive much attention until German astronomer Johann Bode restated it in 1772. By then, Titius had been all but forgotten, and the formula became known as Bode's Law.)

On the night of January 1, 1801, Italian astronomer Giuseppe Piazzi discovered the first asteroid. He observed a starlike body that was not listed in star catalogues. It was moving faster than Mars yet slower than Jupiter, so he deduced it must lie between the two. He named the asteroid Ceres, the Roman goddess of agriculture. Later, Ceres was found to be in the right place to satisfy Bode's Law.

In the mid-1800s, with the improvement of telescopic equipment and techniques, many new asteroids were discovered. There are now more than 5,000 tracked and documented asteroids, an additional 13,000 identified, and an estimated total of 1,000,000. About 100,000 asteroids are bright enough to be photographed from Earth. Only one, Vesta (the fourth one discovered), is bright enough to be seen with the naked eye.

Asteroid belt

Most asteroids lie in a main belt between the orbits of Mars and Jupiter. This belt is divided into smaller belts, separated by distances known as Kirkwood gaps (named for their discoverer, nineteenth-century

American astronomer Daniel Kirkwood). Kirkwood gaps are spaces in which the gravitational attraction of Jupiter prevents any object from maintaining an orbit.

Not all asteroids reside in the main belt. Trojan asteroids are located in two clusters, one on either side of Jupiter. This arrangement is a consequence of the gravitational attraction of Jupiter and the Sun. Another class of asteroids crosses the orbits of several planets.

Impacts with Earth

One group of asteroids, called Apollo objects, cross Earth's orbit. These bodies may come relatively close to Earth, and some have even collided with the planet. In 1908, an asteroid about one-tenth of a mile in diameter came through the atmosphere and exploded above central Siberia. The blast produced a mushroom cloud, wiped out a herd of reindeer, scorched and uprooted trees for miles around, and shattered windows 600 miles away. Asteroids ten times the size of this Siberian asteroid are estimated to hit Earth every few hundred thousand years.

Some 65 million years ago an asteroid struck Earth off the northern tip of the Yucatan Peninsula of Mexico. The asteroid, known as Chicxulub (pronounced cheek-soo-LOOB), left a crater under the Gulf of Mexico with an estimated diameter of 110 miles (177 kilometers). Some scientists believe the resulting inferno from the impact incinerated hundreds of thousands of species of plant and animals, and caused the extinction of the dinosaurs.

About 250 million years ago, an asteroid 4 to 8 miles (6.4 to 12.8 kilometers) across slammed into Earth with the force of more than a million earthquakes, setting off what scientists theorize was the most catastrophic of mass extinctions. The impact carved out a crater some 75 miles (121 kilometers) wide and caused huge volcanic eruptions that buried much of the planet in lava. It blasted millions of tons of rock and dust into the sky, blotting out the Sun's rays. It also brought about changes in sea levels and climatic shifts. These changes killed 90 percent of the marine species and 70 percent of the backboned land animals that lived during that geologic period. Scientists discovered evidence of this devastating extinction by digging deep into Earth's core. Trapped with soccer-ball-shaped carbon molecules called buckminsterfullerenes or buckyballs, scientists found a mix of helium and argon gases similar to that found in certain stars but unlike anything that could form naturally on Earth.

Scientists now believe a flurry of asteroids barraged Earth and the Moon some 4 billion years ago, roughly the same time life was forming

on the planet. In a study released at the end of 2000, scientists reported that a rain of asteroids lasting from 20 million to 200 million years melted rocks, blasted out craters, and reshaped the surface of both the Moon and Earth. On the Moon, the bombardment produced the great basins that are clearly visible from Earth. The asteroids that slammed into Earth, ten times larger than the Chicxulub asteroid, blasted craters rim to rim the size of present-day continents, vaporized the oceans, and filled the atmosphere with life-choking fog. Some scientists theorize that the impacts may have affected the evolution of life, forcing it to begin anew, or may have brought minerals, water, or even the building blocks of life to the planet.

Orbiting, then landing on, an asteroid

In April 2000, after traveling some 2 billion miles (3.2 billion kilometers) since it left Earth on February 17, 1996, the unmanned spacecraft NEAR (Near Earth Asteroid Rendezvous) Shoemaker began a circular orbit around the asteroid Eros. It was the first time a spacecraft had orbited an asteroid. During its one-year mission around Eros, the 1,100-pound (500-kilogram) spacecraft settled into an orbit that at one point was as close 3 miles (5 kilometers) above the potato-shaped asteroid. Eros, named after the Greek god of physical love, is one of the larger asteroids in the solar system, measuring about 21 miles (34 kilometers) long and 8 miles (13 kilometers) thick. It is called a near-Earth asteroid because its orbit crosses that of Earth and poses a potential collision danger. Scientists estimate it is 4.5 billion years old, almost unchanged since the beginning of the solar system.

Loaded with six instruments, NEAR Shoemaker took measurements to determine the mass, density, chemical composition, and other geological characteristics of the asteroid. It also beamed back to Earth some 160,000 images of Eros. On February 12, 2001, NEAR Shoemaker used the last of its fuel in an attempt to land on the surface of Eros. The craft had not been designed with landing gear, and mission scientists had given it a 1 percent chance of survival. Bumping into the asteroid at a mere 4 miles (6.4 kilometers) per hour, however, the hardy spacecraft survived, becoming the first spacecraft to land on an asteroid. On its way down to the surface, NEAR Shoemaker continued to transmit

pictures back to Earth. Once on the surface, it continued to collect invaluable data about the oddly shaped asteroid. Even though scientists will probably study the data for years, they did learn early on that the asteroid does not tumble wildly through space. Instead, it rotates around one axis, much like a planet.

An end to its successful five-year, $225 million mission came on February 28, 2001, when scientists put NEAR Shoemaker into a planned hibernation. Scientists did not believe the spacecraft would survive the frigid darkness of winter on Eros, when temperatures would plummet to −238°F (−150°C). There is a very slight chance it might come alive again sometime in 2002 when full sunlight returns to that part of the asteroid.

[*See also* **Meteors and meteorites**]

Asthma

Asthma is a reversible lung disease that affects approximately four million people in the United States. It is sometimes referred to as a disease of twitchy or reactive lungs, which means that the airways of the lungs are extremely sensitive to irritants such as pollen, animal dander (hair, feathers, or skin), dust, or tobacco smoke. When these irritants are inhaled, the airways react by constricting or narrowing. In some people, asthma attacks follow a cold or a severe respiratory infection. Stress, exercise, and even changes in temperature or humidity can bring on attacks of asthma, as can certain drugs such as aspirin.

Some people with asthma have only mild symptoms that occur from time to time. Others have symptoms that occur frequently and that can be mild, moderate, or severe in nature. Severe asthma attacks are sometimes life threatening. Although researchers have learned more about the underlying causes of asthma in recent years, there is no specific treatment for the disease. In fact, deaths from asthma are on the rise. Many experts believe that lack of standard treatments and inconsistent monitoring of asthma patients have contributed to this increased rate of death.

How asthma affects the airways

The airways are tubes called bronchi that branch into smaller tubes called bronchioles. They carry air from the windpipe to the lungs. During an asthma attack, the airways are narrowed due to muscle spasms, swelling and inflammation of the airway walls, and the production of large amounts of mucus. This results in a blocking of the passage of air to the

Words to Know

Bronchi: The two main airway tubes that branch off from the windpipe and lead to each lung.

Bronchiole: Any of the smaller airway tubes that branch off from the bronchi.

Bronchodilator: A drug, either inhaled or taken orally, that widens the lung airways by relaxing the smooth muscles of the airways.

Constriction: In asthma, the characteristic narrowing of the airways.

lungs. The characteristic sign of asthma is wheezing, the noisy whistling sound that a person makes as he or she tries to push air in and out of narrowed airways. Other symptoms include the sensation of a tight chest, shortness of breath (breathlessness), and a cough.

Treatment of asthma

Treatment of asthma aims at opening the airways and reducing inflammation. There are two general categories of medications used to treat the disease: those that bring quick relief in the sudden onset of an asthma attack and those used long-term to control persistent asthma. The treatment used may vary from patient to patient, based on individual need. While an inhaler may be used occasionally in very mild cases, often a combination of drugs is prescribed for moderate to severe forms. Extremely severe, or acute, attacks of asthma may require the patient to be hospitalized.

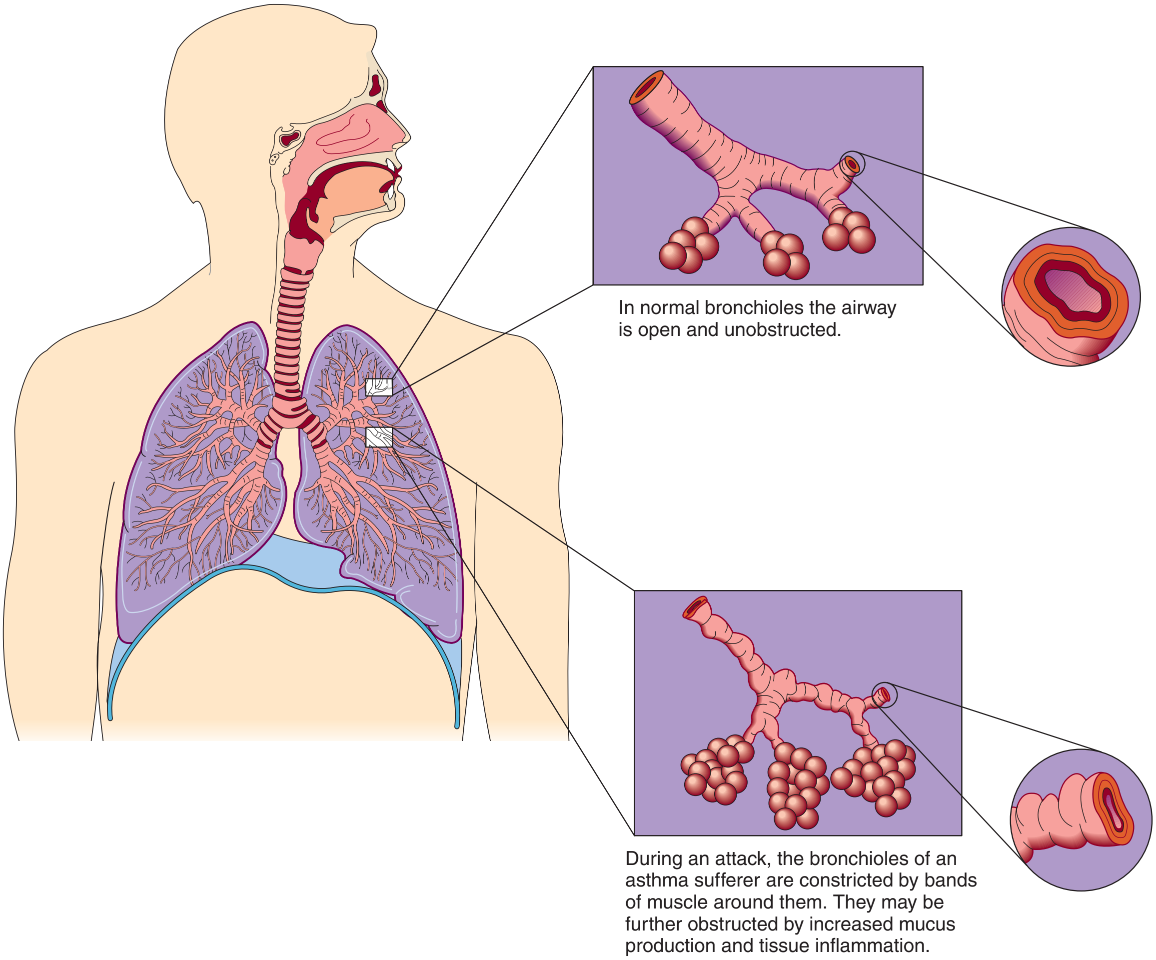
Bronchodilators are drugs that dilate, or widen, constricted lung airways by relaxing the smooth muscles of the airways. They can either be inhaled through a special device or taken orally (by mouth) in pill form. Inhaled bronchodilators are usually prescribed for mild to moderate forms of asthma. Because they are applied directly to the constricted airways, they act quickly; the patient is instructed to inhale the drug as soon as he or she feels an attack coming on. Oral bronchodilators are longer acting and are usually prescribed for severe asthma. A new, longer-acting bronchodilator called Salmeterol™, which is inhaled, combines the direct effects of inhaled bronchodilators with the long-lasting protection of oral ones. It is useful in maintaining clear airways and in preventing

nighttime flare-ups of asthma, as well as those caused by such stimuli as exercise and changes in temperature.

The inflammation associated with asthma has a direct effect on lung function. Increased emphasis has been placed on the use of anti-inflammatory drugs to reduce swelling and inflammation of the airways. In cases of persistent asthma, it is often recommended that anti-inflammatory medications, such as corticosteroids (pronounced kor-tik-oh-STEH-roydz), be taken on a daily basis. They can either be inhaled or taken in pill form.

Another medication commonly used in the treatment of asthma is Cromolyn™, a drug that blocks the release of histamine. Histamine is a chemical that the body produces in response to allergy-causing substances. Its release prompts constriction of the airways, which results in difficulty

A comparison of normal bronchioles and those of an asthma sufferer. *(Reproduced by permission of The Gale Group.)*



breathing. Cromolyn™ is used to prevent asthma attacks rather than as a treatment during attacks.

Managing asthma and preventing attacks

The key to managing asthma and preventing attacks is the patient's ability to recognize the factors that trigger an attack—and then making the conscious effort to avoid them. Since allergies and asthma often go hand in hand, allergy testing may be an effective way to identify allergens (allergy-causing substances) in some patients. If asthma is brought on by exercise, finding a level of exertion that is comfortable or using an inhaled bronchodilator before exercise may help to control symptoms. Taking medicine as prescribed is also an important factor in maintaining control of the disease.

For all persons with asthma, the most important aspect of managing their disease is communication with and regular visits to their physician. It is essential that patient and physician work together to monitor progress and keep abreast of any changes in the patient's condition.

[*See also* **Respiratory system**]

Astrophysics

Astrophysics uses the already understood theories of physics (the study of matter and energy) to describe astronomical (universal) phenomena or events. Astrophysicists try to understand the processes that cause our universe and everything in it to behave the way it does.

Background

For thousands of years, humans observed phenomena in the sky, but had no physical explanation for what they saw. Scientists in the twentieth century, however, have been able to explain many astronomical phenomena in terms of detailed physical theories, relating them to the same chemistry and physics at work in our everyday lives.

Whereas experiments in many other scientific fields can be performed under controlled conditions in a laboratory, astrophysical experiments cannot: the energies and distances involved are simply too great. Even though conditions vary greatly throughout the universe, astrophysicists can observe events in the sky and then develop theories about those

events based on the laws that govern our day-to-day experiences on Earth. It is common belief that the laws of physics are consistent throughout the universe.

Processes in the universe

The first astrophysical concept or law to be recognized was the law of gravity. Although it is a very weak force compared to the other fundamental forces of nature, gravity is the dominant factor determining the structure and the fate of the universe. The force of gravity acted over vast distances of space to bring together large structures, such as galaxies, and smaller ones, such as stars and planets. However, scientists generally hold the view that the understanding of the interaction and behavior of atoms marks the true beginning of astrophysics. Indeed, even such enormous objects as stars are governed by the action of atoms.

The Hubble Space Telescope (HST) captured this image of the Cartwheel galaxy. Large space-based observatories, such as the HST, lead to major advances in astrophysics by exploring unknown parts of the universe. *(Reproduced by permission of the National Aeronautics and Space Administration.)*

Importance of instrumentation

Recent advances in space instrumentation have allowed astrophysicists to observe astronomical phenomena that previously had been too far away to see. Large space-based observatories, such as the Hubble Space Telescope, continually lead to major advances in astrophysics by exploring parts of the universe with a sensitivity never before imagined. Space probes, such as the *Voyagers,* which visited most of the outer planets of our solar system, have provided detailed measurements of the physical environment throughout our solar system. Spectroscopes, optical devices that analyze electromagnetic radiation (energy in the form of waves or particles), have enabled astrophysicists to determine the chemical composition of distant stars or galaxies.

[*See also* **Cosmology; Galaxy; Infrared astronomy; Quasar; Relativity, theory of; Solar system; Star; Sun; Telescope; Ultraviolet astronomy; X-ray astronomy**]

Where to Learn More

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Discover. Published by Walt Disney Magazine, Publishing Group, 500 S. Buena Vista, Burbank, CA 91521. Also online at www.discover.com.

National Geographic. Published by National Geographic Society, 17th & M Streets, NW, Washington, DC 20036. Also online at www.nationalgeographic.com.

New Scientist. Published by New Scientist, 151 Wardour St., London, England W1F 8WE. Also online at www.newscientist.com (includes links to more than 1,600 science sites).

Popular Science. Published by Times Mirror Magazines, Inc., 2 Park Ave., New York, NY 10024. Also online at www.popsci.com.

Science. Published by American Association for the Advancement of Science, 1333 H Street, NW, Washington, DC 20005. Also online at www.sciencemag.org.

Science News. Published by Science Service, Inc., 1719 N Street, NW, Washington, DC 20036. Also online at www.sciencenews.org.

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Smithsonian. Published by Smithsonian Institution, Arts & Industries Bldg., 900 Jefferson Dr., Washington, DC 20560. Also online at www.smithsonianmag.com.

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Web Sites

Cyber Anatomy (provides detailed information on eleven body systems and the special senses) *http://library.thinkquest.org/11965/*

The DNA Learning Center (provides in-depth information about genes for students and educators) *http://vector.cshl.org/*

Educational Hotlists at the Franklin Institute (provides extensive links and other resources on science subjects ranging from animals to wind energy) *http://sln.fi.edu/tfi/hotlists/hotlists.html*

ENC Web Links: Science (provides an extensive list of links to sites covering subject areas under earth and space science, physical science, life science, process skills, and the history of science) *http://www.enc.org/weblinks/science/*

ENC Web Links: Math topics (provides an extensive list of links to sites covering subject areas under topics such as advanced mathematics, algebra, geometry, data analysis and probability, applied mathematics, numbers and operations, measurement, and problem solving) *http://www.enc.org/weblinks/math/*

Encyclopaedia Britannica Discovering Dinosaurs Activity Guide *http://dinosaurs.eb.com/dinosaurs/study/*

The Exploratorium: The Museum of Science, Art, and Human Perception *http://www.exploratorium.edu/*

ExploreMath.com (provides highly interactive math activities for students and educators) *http://www.exploremath.com/*

ExploreScience.com (provides highly interactive science activities for students and educators) *http://www.explorescience.com/*

Imagine the Universe! (provides information about the universe for students aged 14 and up) *http://imagine.gsfc.nasa.gov/*

Mad Sci Network (highly searchable site provides extensive science information in addition to a search engine and a library to find science resources on the Internet; also allows students to submit questions to scientists) *http://www.madsci.org/*

The Math Forum (provides math-related information and resources for elementary through graduate-level students) *http://forum.swarthmore.edu/*

NASA Human Spaceflight: International Space Station (NASA homepage for the space station) *http://www.spaceflight.nasa.gov/station/*

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The Particle Adventure (provides an interactive tour of quarks, neutrinos, antimatter, extra dimensions, dark matter, accelerators, and particle detectors) *http://particleadventure.org/*

PhysLink: Physics and astronomy online education and reference *http://physlink.com/*

Savage Earth Online (online version of the PBS series exploring earthquakes, volcanoes, tsunamis, and other seismic activity) *http://www.pbs.org/wnet/savageearth/*

Science at NASA (provides breaking information on astronomy, space science, earth science, and biological and physical sciences) *http://science.msfc.nasa.gov/*

Science Learning Network (provides Internet-guided science applications as well as many middle school science links) *http://www.sln.org/*

SciTech Daily Review (provides breaking science news and links to dozens of science and technology publications; also provides links to numerous "interesting" science sites) *http://www.scitechdaily.com/*

Space.com (space news, games, entertainment, and science fiction) *http://www.space.com/index.html*

SpaceDaily.com (provides latest news about space and space travel) *http://www.spacedaily.com/*

SpaceWeather.com (science news and information about the Sun-Earth environment) *http://www.spaceweather.com/*

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